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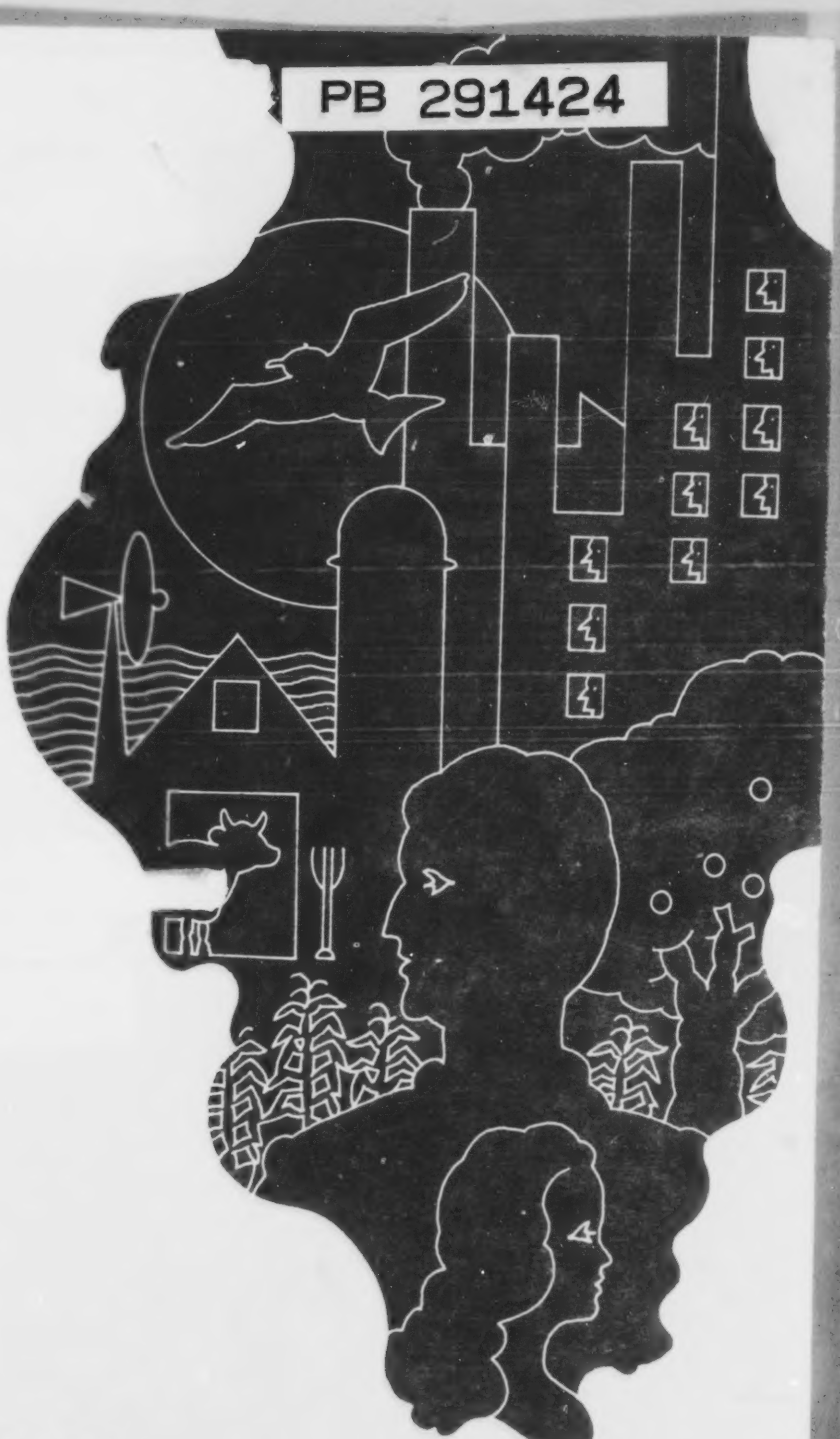

THE ECONOMIC IMPACT OF TOTAL DISSOLVED SOLIDS EFFLUENT STANDARDS IN ILLINOIS

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In 1971, the Illinois Pollution Control Board adopted effluent standards to maintain and protect water quality within the state. According to Rule 408 of Chapter 3 of the Water Pollution Regulations, 22 pollutants were limited in discharges to specific concentrations. The technical feasibility of achieving these limitations was one of the primary bases considered in the promulgation of these values.

The major emphasis of this report is to address the economic impact resulting from either (a) maintaining the existing TDS standard, or (b) adoption of a new TDS standard that would allow the Village of Sauget to come into compliance.

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by

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IIT Research Institute

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Opinion of the Economic Technical Advisory Committee of the Illinois Institute for Environmental Quality

The Committee has reviewed the economic impact study entitled: The Economic Impact of Total Dissolved Solids Effluent Standards in Illinois. We find the report to be generally responsive to the requirements of Sec. 6 of the Environmental Protection Act, and recommend that it be forwarded to the Pollution Control Board so that economic impact hearings may be held in connection with R75-6, Total Dissolved Solids, Rule 408(6).

The Committee notes in Chapter 3 that a significant proportion of the total dissolved solids is unaccounted for in the plant waste streams. This economic study assumes that all effluent standards other than total dissolved solids are being met. Further examination of these waste streams could change the conclusions of this study, particularly if an appreciable fraction of the unaccounted materials consist of metals or metalloids, such as cadmium, mercury, chromium, arsenic, etc.

August 31, 1976

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Chapter 1

INTRODUCTION

In 1971, the Illinois Pollution Control Board adopted effluent standards to maintain and protect water quality within the state. According to Rule 408 of Chapter 3 of the Water Pollution Regulations, 22 pollutants were limited in discharges to specific concentrations. The technical feasibility of achieving these limitations was one of the primary bases considered in the promulgation of these values.

An amendment to the total dissolved solids (TDS) effluent standard, Rule 408(b), has been proposed by the Village of Sauget. The proposed amendment would exempt the Mississippi River from the TDS effluent standard, provided the applicable water quality standards are achieved after the mixing zone. The basic reasons presented by the Village of Sauget for the rule change were:

1. Effluents discharging to the Mississippi River in excess of 3,500 mg/ℓ would not create a water pollution problem.
2. The cost of compliance with the TDS effluent standard is expensive and economically unreasonable.
3. The effluent standard of 3,500 mg/ℓ does not encourage the use of recycling techniques.

The major emphasis of this report is to address the economic impact resulting from either (a) maintaining the existing TDS standard, or (b) adoption of a new TDS standard that would allow the Village of Sauget to come into compliance. An economic impact analysis provides an assessment of the change in prices, output, and employment experienced by the affected dischargers. These changes are the results of increased costs of operation associated with the stipulated pollution control requirements. In addition, the costs and benefits of the total dissolved solids standard must be compared as required under Illinois law (Public Act 79-790).

While the proposed regulatory change is limited to the Mississippi River, which would effect primarily Sauget, other dischargers in Illinois also violate the existing TDS effluent standard. Thus, to provide an overall view of the existing compliance situation, the other dischargers currently in violation are identified. In addition to the point sources of municipal and industrial dischargers, there are other sources which contribute to the TDS levels occurring in Illinois rivers and streams. These other sources are described and an estimate of their level of contribution is presented. Such information not only augments the technical analysis but also the assessment of economic impact, which is the primary objective of this study.

From the information presented herein: a summary of the existing conditions with respect to dischargers and water quality, the economic impact of TDS regulation on the Village of Sauget, and a review of the benefits and costs of regulation; valuable information is gained. Such data should constitute a useful input to the decision-making process regarding total dissolved solids standards in Illinois.

Chapter 2

EXECUTIVE SUMMARY

The objective of effluent and water quality standards is protection of the rivers and streams for water users and the existing biota. In ascertaining the appropriate level of regulation, the economic ramifications of such requirements should be considered. The Village of Sauget has proposed that the Mississippi River be exempt from the present maximum allowable total dissolved solids (TDS) effluent standard of 3,500 mg/ℓ.

Prior to describing the actual economic impact and cost-benefit analyses, the impact of the existing regulation on industrial dischargers are delineated. First, the discharger groups currently in violation of the TDS effluent standard are identified. The contribution of industrial dischargers, both in-compliance and out-of-compliance, to the environment are presented along with the TDS contributions from other sources. The existing TDS water quality in Illinois waterways is then described. Once the technical background data on the existing situation has been presented, the economic impact on Sauget is reviewed. Cost-benefit analyses, one dealing with Sauget specifically and the other pertaining to the entire state, are included to provide some indication of the allocation of resources with the current TDS regulation.

The Village of Sauget is one of the largest point source contributors of TDS to Illinois waterways, but they are far from being the only violator. Sauget has five industrial dischargers which contribute over 99% of the TDS loading on the Village treatment plant. Since 1965, the volume of wastewater has been gradually reduced from 38 million gallons per day (MGD) to a 1976 projected flow of 8 MGD. The flow reductions by the five industrial plants are at least partially responsible for the current TDS violation. Table 2-1 contains a summary of the flow and TDS loadings contributed by each plant in the Village of Sauget. The majority of the TDS is generated in the manufacturing processes of three plants: Monsanto, Edwin Cooper, and Amax Zinc.

In addition to the Village of Sauget, the Illinois Environmental Protection Agency (IEPA) identified 10 dischargers in 1973-74 and eight dischargers in 1974-75 that exceeded the maximum allowable 3,500 mg/ℓ TDS. The Illinois effluent standard allows each discharger to increase the TDS concentration 750 mg/ℓ above the background level, with an allowance for recycling of water up to a maximum of 3,500 mg/ℓ. In 1974-75, the IEPA monitoring program identified 150 dischargers with over 1,000 mg/ℓ TDS in their effluent. Without ascertaining the degree of water recycling practiced at each of these plants, it was not possible to determine which ones were in violation of the "add 750 mg/ℓ" TDS standard. Specific groups of dischargers are currently affected by the TDS standards in Illinois. These groups include the coal mining industry, water treatment plants utilizing zeolite softeners, and the power generating industry. Thus, while the proposed TDS rule change would provide relief for Sauget, there are many other dischargers in the state with similar problems.

In evaluating the impact of a rule change, it is important to assess not only the existing effluent situation but also the water quality conditions within the state. Because dissolved solids are a natural occurrence in streams, the contributions of point and non-point sources should be distinguished.

A state-wide weighted average TDS concentration of 303 mg/ℓ was reported in a recent study by Flemal and Nienkerk. This study found that total dissolved solids levels in Illinois streams are consistent by regional area. Table 2-2, which presents the river basins with TDS water quality greater than 1000 mg/ℓ based upon the 1975 IEPA monitoring data, demonstrates

Table 2-1

DISCHARGER PROFILES FOR VILLAGE OF SAUGET

	Industrial Source	SIC Code	Present Water Use(MGD)[1]	Projected Water Use(MGD)[2]	Projected Total Dissolved Solids Concentration(3)	Projected Total Dissolved Solids Loading(3) (pounds per day)
1.	W.C. Krummrich Plant of Monsanto Corp.	2818	10.9	6.6	10,639	587,770
2.	Amax Zinc Corp.	3333	5	0.3	18,000	53,000
3.	Cerro Copper	1430, 3022	2.04	2.02	650	11,000
4.	Midwest Rubber Reclaiming Plant	3069	1.78	0.05	1,200	470
5.	Edwin Cooper	2818	2	1.15	7,450	94,300
	TOTAL		21.72	10.12		746,540 (4)

---

(1) Values taken from U.S. EPA, NPDES permit application (1972).

(2) Values taken from data presented by companies

(3) Data presented by companies. Monsanto values are before neutralization and Amax values are projected on basis of flow reduction plan.

(4) Before neutralization at Village treatment plant.

Table 2-2

RIVER BASINS WITH WATER QUALITY VIOLATIONS

River Basin	Number of Stations with TDS levels > 1000 mg/ℓ	Maximum TDS (mg/ℓ) for Samples Taken
Saline	11	3,300
Little Wabash	1	1,000
Illinois	1	1,000
Des Plaines (G)	30*	1,590
(H)	17*	3,760
Mississippi (South)	4	2,000
Big Muddy	7	1,740
Kaskaskia	4	2,100
Lake Michigan	1	1,010
Rock River	1	1,000
Total	77	

*Stations located in secondary contact waters that the regional TDS patterns can be observed by the location of the affected rivers. The Des Plaines River in northeastern Illinois and the Saline and Big Muddy Rivers, which run through the surface mining areas, have the greatest number of stations in violation and the highest TDS levels. Regional water quality analyses thus indicate the areas of concern within Illinois.

It is important to distinguish the contribution of point and non-point sources to TDS water quality levels in the streams. A mass balance was estimated around the seven major rivers in Illinois which drain 94% of the state. Utilizing flow and TDS concentration data, the total quantity of TDS (pounds/day) was computed for various stream conditons. Eight major sources were identified, and the contribution of each is shown in Table 2-3.

Several of the sources, including road de-icing, background from Lake Michigan, and domestic waste, contribute more dissolved minerals than does the industrial sector discharging greater than 1,000 mg/ℓ. Storm-water runoff alone contributes more pounds of TDS than all other sources combined. The industrial sector discharging greater than 1,000 mg/ℓ is directly affected by the Illinois TDS effluent regulation, while the regulation has little or no effect on the other sources, which apparently account for 97% of the total TDS loading.

Once the background information concerning the number of dischargers in violation, the existing water quality, and the contributions of TDS from various sources had been assembled, the economic impact upon the Village of Sauget was prepared. In order for Sauget to comply with the 3,500 mg/ℓ maximum TDS standard, a reverse osmosis treatment plant with deep well disposal of the brine stream had been recommended by the Village's consultant. There is some question as to the acceptability of deep well disposal of this brine stream, both from a regulatory point of view and from the geology in the Sauget area. Two other brine disposal alternatives, solar evaporation ponds and multi-effect evaporators, were considered to reflect the total

Table 2-3

TDS MASS BALANCE FOR ILLINOIS

Source	Average TDS Discharged to Illinois Waterways, 10^6 lb/day	Percent of Total TDS[1] Loading, %
Background from Lake Michigan	2.85	6.5
Domestic waste contribution	1.90	4.3
Background from municipal ground water	1.25	2.8
Background from industrial ground water	1.08	2.4
Road de-icing	1.64	3.7
Irrigation	0.19	0.4
Industrial contribution		
$<$1,000 mg/ℓ	4.16	9.4
$>$1,000 mg/ℓ	1.38	3.1
Storm-water runoff	28.9	65.5
Total	43.35	98.3

---

[1] Average TDS leaving the state via the seven rivers presented in Table 5-1 is 44.1 x 10^6 lb/day.

range of possible treatment costs. The treatment costs for reverse osmosis with the alternative disposal methods are presented in Table 2-4. These costs were allocated among the industrial firms according to the proportion of TDS contributed as shown previously in Table 2-1. Table 2-5 presents the cost allocations by firm which were used to determine the economic impact upon the Village of Sauget.

The response of each industrial discharger in Sauget to additional imposed costs for TDS is based on the economic condition of the plant and the magnitude of the treatment cost burden. In each case, a microeconomic decision regarding price increases or decreases in production is related to the plant's finances. There is uncertainty with regard to the actual decision, and thus, only a range of probable reactions is appropriate for such an evaluation. To develop this possible range, the following three scenarios were considered for each discharger:

a) Pay costs of treatment for TDS

b) Close production facilities associated with TDS contributions

c) Combination of "a" and "b" responses.

The three scenarios described provided a range of anticipated responses, and according to the costs incurred, each plant will adjust output, employment, prices, and plans for expansion. For each of the five dischargers, a range of responses was evaluated. This range represents the attitudes of the plants surveyed and an evaluation of their economic condition. The final results of this analysis are summarized in Table 2-6 for each of the five industries in Sauget.

According to Table 2-6, enforcement of the existing TDS regulation will probably have a negligible effect on Cerro Copper and Midwest Rubber Reclaiming. Enforcement of the present standard would probably reduce Amax Zinc's expansion plans at Sauget, but would have a negligible effect on the current production

Table 2-4

SUMMARY OF CAPITAL AND ANNUAL COSTS* FOR REVERSE OSMOSIS PLANT WITH BRINE DISPOSAL AT SAUGET

	Alternative		
	R.O. with Deep Well Disposal	R.O. with Multi-Effect Evaporator	R.O. with Solar Evaporation Ponds
Total Capital Investment	7,720,000	10,300,000	12,300,000
Annual Costs			
Annualized Capital	900,000	1,200,000	1,380,000
Electrical	260,000	240,000	250,000
Fuel (Coal)	30,000	880,000	30,000
Operating Labor	120,000	210,000	120,000
Maintenance	230,000	300,000	300,000
Chemicals	200,000	200,000	200,000
Sludge Disposal	—	1,000,000	1,250,000
Total Annual Cost	$1,740,000	$ 4,030,000	$ 3,530,000

* 1975 dollars

Table 2-5

COST ALLOCATION BY INDUSTRY

Alternative 1 -- Reverse Osmosis with Deep Well Disposal

	Monsanto	Edwin Cooper	Amax Zinc	Cerro Copper	Total
Capital Invest., $	6,080,000	970,000	550,000	120,000	7,720,000
Annual Cost[1], $	1,370,000	220,000	120,000	30,000	1,740,000

Alternative 2 -- Reverse Osmosis with Multi-Effect Evaporator

	Monsanto	Edwin Cooper	Amax Zinc	Cerro Copper	Total
Capital Invest., $	8,110,000	1,300,000	730,000	150,000	10,300,000
Annual Cost[1], $	3,170,000	510,000	290,000	60,000	4,030,000

Alternative 3 -- Reverse Osmosis with Solar Evaporation Ponds

	Monsanto	Edwin Cooper	Amax Zinc	Cerro Copper	Total
Capital Invest., $	9,700,000	1,550,000	870,000	180,000	12,300,000
Annual Cost[1], $	2,790,000	440,000	250,000	50,000	3,530,000

---

[1] Includes Annualized Capital Investment

Table 2-6

SUMMARY OF ECONOMIC RESPONSES TO TDS REGULATION

Company	SIC	Possible Price Change (% Sales)	Possible Output Change (%)	Possible Number of Employees Change	Possible Expansion Losses
Monsanto	2818	0 - 1.0	0 - 46	0 - 600	1st year: 5% output + 35 jobs; no future expansion
Edwin Cooper	2818	0 - 1.3	0 - 37	0 - 52	25% additional output + 35 jobs
Amax Zinc	3333	0 - 0.5	0	0	10% output + 45 jobs
Cerro Copper	3351	0 - 0.07	0	0	no effect
Midwest Rubber Reclaiming	3031	0	0	0	no effect
Total				0 - 652	0-115 jobs plus future effects now unknown

facilities. Monsanto and Edwin Cooper would potentially lose between 0-600 and 0-52 employees, respectively, from enforcement of the existing regulation. In addition to a possible projected drop in production at Monsanto and Edwin Cooper from enforcement of the standard, future expansion plans would also be hampered. In fact, major impact upon Sauget is the loss of future expansion due to costs of TDS and enforcement of some upper limit. Present production capacities could be reduced in the long run due to increased costs of operation. Only estimates of the probable range of responses is described due to the complexity of the microeconomic decisions performed by each plant.

Since the Sauget petition is a localized problem, there will be negligible statewide effects. However, the community of Sauget could potentially be severely effected depending upon the response of the industrial dischargers. Loss of present and future jobs is a possible result, and this is an important local effect since the East St. Louis area has the highest unemployment rate in the state.

The costs of compliance for the Village of Sauget must also be utilized to determine the associated benefit-cost analysis of the TDS regulation. The measurement of benefits and costs provides an indication of the resource allocation which is occurring.

The benefit-cost analysis of a TDS regulation is not as straightforward as that for a toxic or hazardous material. Toxic substances which damage human health and aquatic life must be removed by dischargers to protect the environment. There really is no alternative for removal of these materials, which can so quickly damage the environment. Pollutants, such as TDS, primarily affect consumers who withdraw surface water for various purposes. Thus, it is possible to consider alternatives to effluent treatment, such as TDS removal by the public water supplies, for minimizing TDS quantities reaching the consumer.

The value of clean water is related to its various uses by consumer groups; and by classifying the potential changes in welfare associated with a change in water quality, it may provide an indirect measure of the willingness to pay. The benefits of improved water quality were measured for 13 potential user categories. In Table 2-7, the results of these estimations are summarized for Sauget and the State of Illinois.

Based on the location of Sauget and potential Mississippi water users, the economic benefits of $460/year can be realized from enforcement of the TDS effluent standard. It should be noted that only Illinois water users downstream of Sauget were considered in this estimation. Actual external effects could be considered for users out of state and located further downstream on the Mississippi River. Since no other state bordering the Mississippi River enforces a TDS effluent standard and the primary concern is believed to be Illinois consumers, the Mississippi River analysis was restricted to Illinois boundaries.

Within the State of Illinois, three user groups, residential water supplies, industrial water supplies, and utilities, were identified as receiving specific economic damage from dissolved solids in water. The residential water users represented the most significant group with a potential reduction in economic damages of $2,200,000 per year. Total benefits in the state which could be quantified equalled $3,120,000.

A comparison of the benefits and costs of TDS regulation offers an indication of the economic efficiency of the enforcement of the standard. By aggregating the potential economic damages incurred in 13 user segments due to TDS, we have gained some insight as to the amount these users would be willing to pay for reduced TDS levels is gained.

In the instance of Sauget, the potential benefits in reduced economic damages were $460 per year, while the annual treatment costs alone were $1,740,000 to $4,030,000. Such a circumstance in which the costs far exceed the benefits does not meet the Pareto criterion or Kaldor-Hicks efficiency criterion. Thus,

Table 2-7

SUMMARY OF TDS ECONOMIC BENEFITS

Benefit Category	Benefit to Users Downstream of Sauget	Benefit to Illinois
Aesthetics	Negligible	Not measured
Agricultural Benefits	Negligible	Negligible
Commerical Fishing	Negligible	Negligible
Residential Water Supply	$220/year	$2,200,000/year
Ecology	Negligible	Not measured
Human Health	Negligible	Negligible
Municipal Water Supply	(Included in residential water supply)	
Industrial Water Supply	None	$860,000/year
Navigation	None	None
Power Generation	$240/year	$60,000/year
Property Value	None	None
Recreation	Negligible	Negligible
TOTAL	$460/year	$3,120,000/year

a benefit-cost analysis is not meaningful in this situation. If the marginal costs and benefits were examined, these curves would be non-intersecting and linear with slopes of zero as shown in Figure 2-1, for the TDS levels of concern. The shape and location of these curves is based on the linear relationships used to develop total cost and benefit estimates and the magnitude of the estimates. These curves would only be applicable for the existing Sauget effluent range. If sufficiently high TDS levels were reached so that other user segments were affected, then the marginal benefit curve would begin to increase, as shown by the dotted lines in Figure 2-1. If the effluent standard were set high enough that no treatment was required by Sauget, the marginal cost curve would, of course, drop rapidly to zero.

The impact on the Village of Sauget if the present TDS standard is enforced is a potential loss from zero to 652 jobs. The actual response by the five firms is not clear at this time, but it is probable that total employment in the area would decrease. In addition, future expansion by the local industries would be reduced if relief from the present standard is not obtained. Other industries in Illinois are in similar positions, and similar economic impacts could be expected. This is especially true with regard to future industrial growth, which would be restricted by the enforcement of the existing standard. The cost-benefit analysis indicated that a more efficient allocation of resources can be achieved through alternative regulatory approaches.

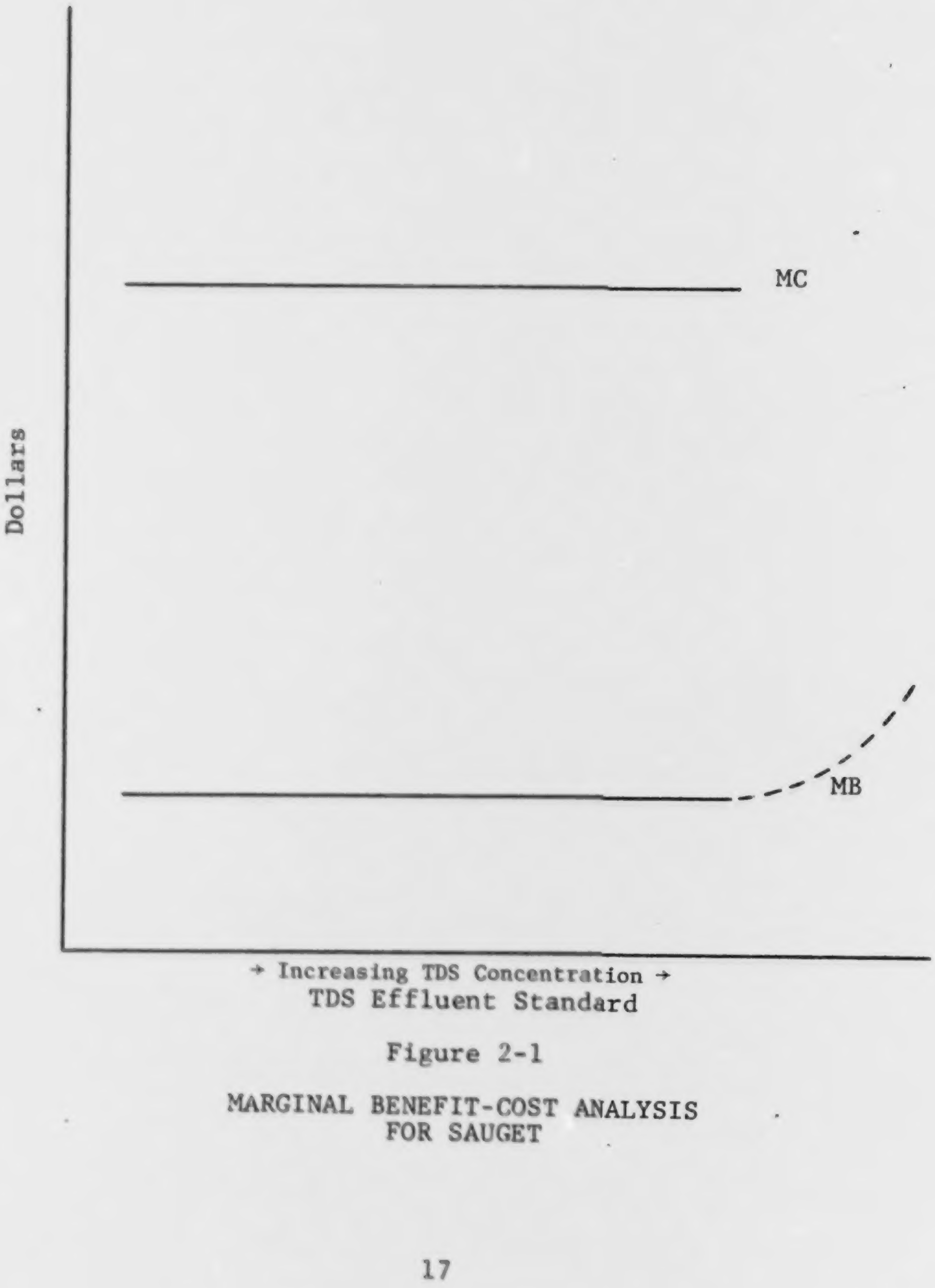

Figure 2-1

MARGINAL BENEFIT-COST ANALYSIS
FOR SAUGET

Chapter 3

DISCHARGERS OF TOTAL DISSOLVED SOLIDS

Because of the ubiquitous nature of total dissolved solids, they can be found in all surface and underground waters. The concentration, however, varies considerably among point source dischargers, depending upon the water usage. Although the Village of Sauget has petitioned for a regulatory change in the total dissolved solids (TDS) effluent limitation specifically for the Mississippi River, there are other dischargers who are also impacted by the present effluent regulations. A description of these affected groups, such as water treatment plants and industrial dischargers, and the magnitude of their problem is presented to indicate the state-wide extent of the TDS problem.

Primary emphasis is given to the industrial dischargers of Sauget, their waste characteristics, and the origin of TDS within the plants. The allocation of TDS contributions is important in ascertaining the economic impact of the existing regulation and identifying the complexity of the problem. The 1975 TDS frequency distribution of Sauget's effluent is also presented to determine the potential compliance of Sauget with alternative effluent standards.

This comprehensive delineation of the TDS compliance problem in Illinois provides background information needed by the Pollution Control Board to assess the merits of any regulatory change.

3.1 Village of Sauget

There are five major industries that discharge to the Village's sewer system. These five industries represent 99% of the total waste flow reaching the sewage treatment plant. The current treatment plant, built in 1965-67, consists of primary treatment and was designed to handle 38 million gallons per day (MGD). The various industries in the Village have, for many years, committed themselves to a flow reduction plan

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within each plant. By 1969, Sauget's average discharge to the Mississippi River was reduced to 25 MGD[1].

In 1970, the Village initiated a plan to upgrade the primary treatment plant to include chemical treatment. The flow at this time was 20 MGD, but a commitment was made to decrease the Village's total flow to approximately 8 MGD. By 1975, the average flow was 15 MGD with the designs completed for achieving the 8 MGD.

With each of the flow reductions accomplished, the total dissolved solids concentration has increased. This was primarily a result of the elimination of once-through cooling water, which had previously diluted the process streams. For the first eight months of 1975, the neutralized effluent TDS concentration averaged 4,595 mg/ℓ, while values above 7,000 mg/ℓ were reported on two occasions during this same period. Shown in Figure 3-1 is the effluent TDS frequency distribution for Sauget. For the eight-month period, the TDS level in Sauget's neutralized effluent exceeded 3,500 mg/ℓ, 94% of the time[2].

Projecting TDS concentration on the basis of additional flow reduction from 15 to 8 MGD indicates that the TDS level could increase as much as 100% above the levels shown in Figure 3-1. Thus, if the TDS standard is maintained on a "not-to-be-exceeded" basis for 24-hour composite samples, Sauget may need an effluent limit as high as 18,000 mg/ℓ to assure compliance at all times. Although the average concentration of 8,000 mg/ℓ is anticipated by Village representatives, approximately 30% of the time the effluent will contain more than 10,000 mg/ℓ TDS. (This assumes that the data of Table 3-1, when doubled, represents the projected effluent quality of the Village.)

The Village of Sauget is currently involved with a regional treatment plant study with surrounding communities. If a regional plant is constructed, with the anticipated 8 MGD contribution from Sauget, the TDS loading will be great enough to prevent the regional plant from achieving the 3,500 mg/ℓ. However, if Sauget maintains their current flow of 15 MGD, the

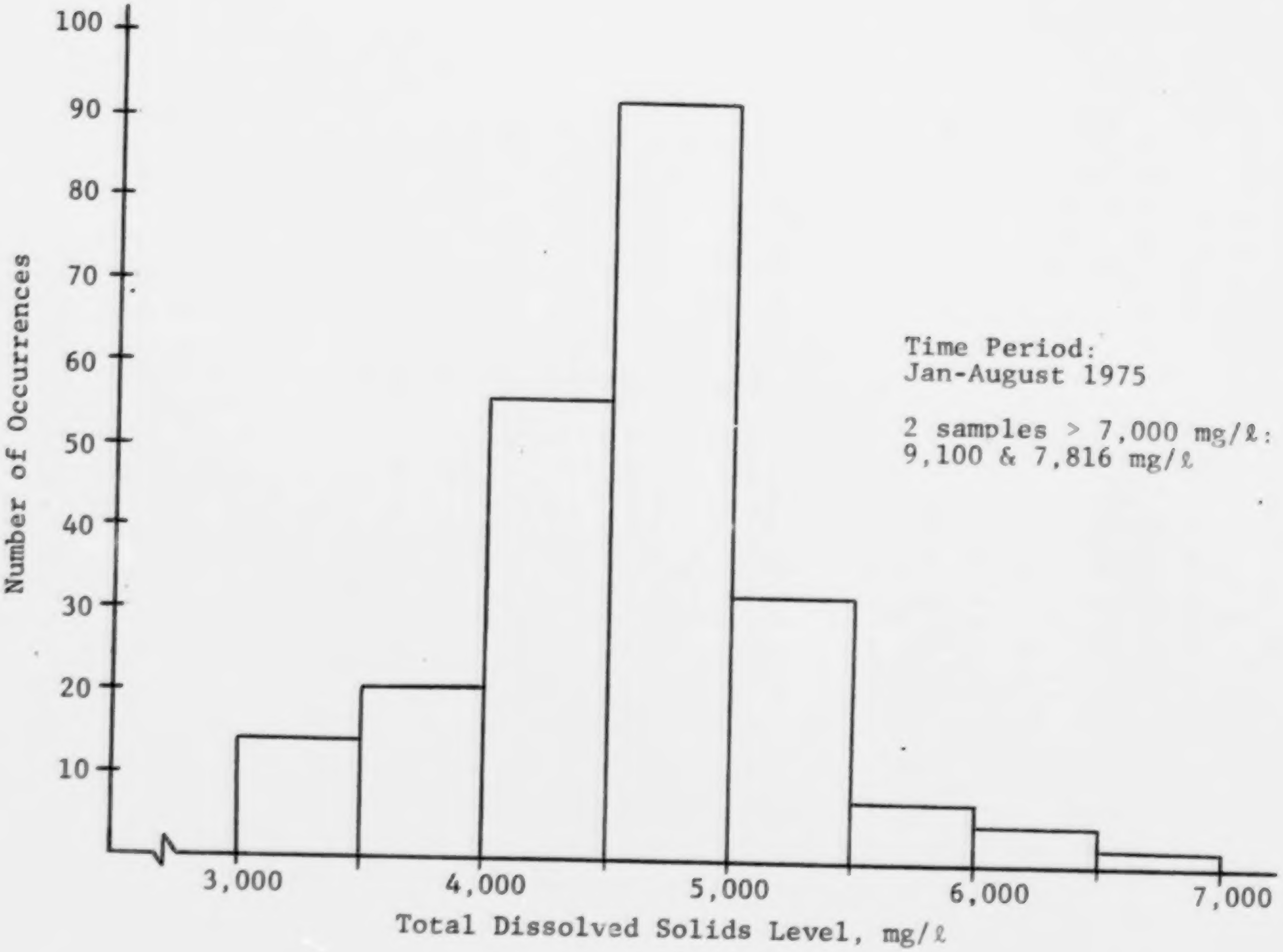

Figure 3-1

FREQUENCY DISTRIBUTION OF EFFLUENT TOTAL DISSOLVED SOLIDS FROM VILLAGE OF SAUGET

Source: Exhibit #5 of Regulatory Hearing R75-6.

Table 3-1

VILLAGE OF SAUGET EFFLUENT CHARACTERISTICS, 1975

	Per Cent of Samples at Various TDS Levels mg/ℓ					
Month	<3500	3500-4000	4000-4500	4500-5000	>5000	Maximum TDS (mg/ℓ)
January	-	7	17	13	63	6320
February	7	-	21	46	25	5830
March	3	16	29	32	19	6294
April	-	-	30	52	18	9100
May	-	-	11	63	26	7816
June	12	19	31	35	4	5316
July	16	10	23	45	6	6520
August	10	19	10	35	3	5024

Source: Exhibit #5 of Regulatory Hearing R75-6.

regional plant would achieve a TDS below 3,500 mg/ℓ, although the total pounds of TDS discharged would be the same in both situations.

3.2 Industrial Dischargers of Sauget

The composition of the effluent from the Village is basically that of five industrial dischargers and the municipal waste of 220 residents plus 2,700 daytime workers. Monsanto Company, Amax Zinc, Cerro Copper, Midwest Rubber, and Edwin Cooper are the primary contributors to the total dissolved solids loading and each will be described accordingly. Any change in the regulation will affect each of these plants in a unique way, and thus it is important to outline specifically the plant problems.

In Table 3-2 the TDS waste profile of each company is summarized. This profile indicates that 98% of the TDS can be attributed to three plants, Monsanto, Amax Zinc, and Edwin Cooper. Although Cerro Copper indicates the second highest flow, the contribution of TDS is smaller than that of the three mentioned. In determining the economic impact of Rule 408(f) on the Village, the flow and TDS loading contributions of each plant must be considered in allocating costs.

The origin of these dissolved solids within each plant demonstrates the integration of processes and generation of total dissolved solids. A description of the manufacturing process associated with each plant which contribute to TDS is provided to demonstrate the complexity of this issue.

3.2.1 W. C. Krummrich Plant, Monsanto Company

According to information provided by the Monsanto Company there are approximately 35 ongoing processes at this plant which produce a variety of organic and inorganic chemicals. The main or basic operation is a caustic-chlorine process with many integrated by-product processes. Wastewaters generated consist of HCl scrubber bottoms, by-product HCl streams, other process waste, and cooling tower blowdown. Alternative methods of treatment include individual treatment of streams, elimination of TDS-generating processes, or treatment of the entire effluent. In considering minimum treatment costs each alternative was evaluated.

Table 3-2

DISCHARGER PROFILES FOR VILLAGE OF SAUGET

	Industrial Source	SIC Code	Present Water Use(MGD)[1]	Projected Water Use(MGD)[2]	Projected Total Dissolved Solids Concentration(mg/ℓ) (3)	Projected Total Dissolved Solids Loading(3) (pounds per day)
1.	W.C. Krummrich Plant of Monsanto Corp.	2818	10.9	6.6	10,639	587,770
2.	Amax Zinc Corp.	3333	5	0.3	18,000	53,000
3.	Cerro Copper	1430, 3022	2.04	2.02	650	11,000
4.	Midwest Rubber Reclaiming Plant	3069	1.78	0.05	1,200	470
5.	Edwin Cooper	2818	2	1.15	7,450	94,300
	TOTAL		21.72	10.12		746,540 (4)

---

(1) Values taken from U.S. EPA, NPDES permit application.

(2) Values taken from data presented by companies

(3) Data presented by companies. Monsanto values are before neutralization and Amax values are projected on basis of flow reduction plan.

(4) Before neutralization at Village treatment plant.

Although there are approximately seven processes with high TDS loadings, the cost of treating these streams in-house and individually was reported by Monsanto[12] to cost more than treating the entire flow at the Village treatment plant. These seven processes are integrated with other plant streams so that it is not possible to isolate and close down the manufacturing sources without closing a substantial portion of the plant. According to Monsanto,[12] the average life of any particular process is approximately three to four years, and thus the nature of the wastewater is continually changing. It appeared from the data presented by Monsanto that treatment of TDS at the Village plant was the most feasible alternative.

The actual composition of the TDS stream from Monsanto has the following characteristics[3]:

Constituent	Pounds per Day
Sulfates	80,000
Chlorides	317,338
Calcium ions	53,000
Sodium ions	51,000
Potassium ions	40,900
Other*	45,032
TOTAL	587,770

Of the 587,770 pounds per day of TDS, only 19,215 pounds or 3.2% are attributed to cooling water contributions. Thus, the process waste streams are significant sources which can only be reduced through elimination or individual treatment, as process modification is not possible according to Monsanto.[12]

3.2.2 Amax Zinc Corp.

Amax's electrolytic zinc refinery is one of 12 plants in the United States producing ingots. A process flowsheet indicating the steps involved in zinc production is shown in Figure 3-2. The dissolved solids associated with this plant are also generated primarily in the processing of zinc.

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* Other includes nitrates, phosphates, ammonium ions, iron, sulfites, and carbonates.

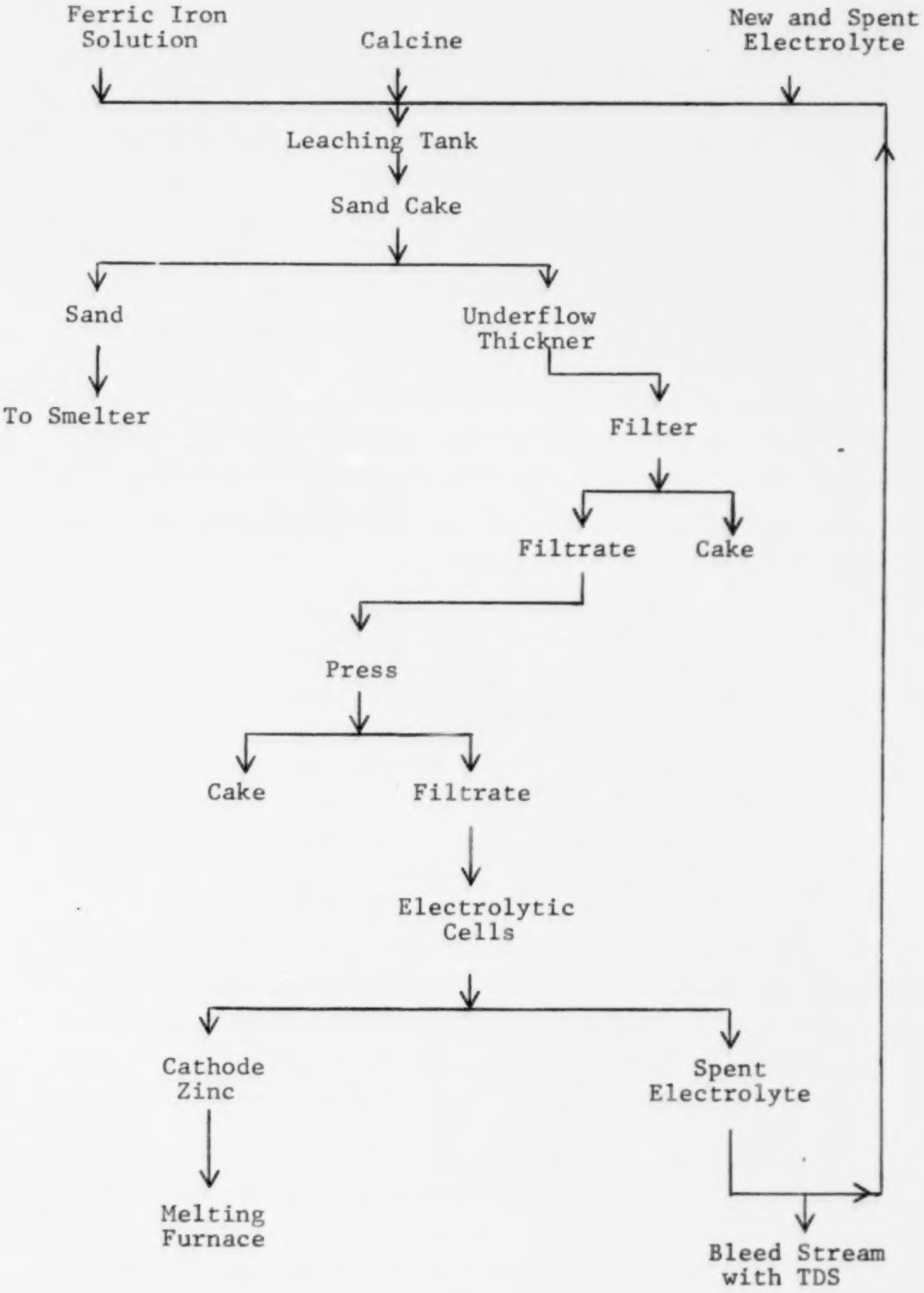

Ferric Iron Solution
Calcine
New and Spent Electrolyte
Leaching Tank
Sand Cake
Sand
Underflow Thickner
To Smelter
Filter
Filtrate
Cake
Press
Cake
Filtrate
Electrolytic Cells
Cathode Zinc
Spent Electrolyte
Melting Furnace
Bleed Stream with TDS

Figure 3-2 TYPICAL FLOWSHEET OF AN ELECTROLYTIC ZINC PLANT

Source: U.S. EPA,"Water Pollution Control in the Primary Non Ferrous Metals Industry," 1973.

The possible sources of TDS are cooling water blowdown, spent electrolyte, gas scrubbing water, and neutralization of acids[4].

Originally, Amax discharged 59,000 pounds per day of TDS in 3.5 MGD at a concentration of 2,057 mg/ℓ. This has been reduced to 1 MGD with 7,199 mg/ℓ of TDS or 59,900 pounds per day. Amax's new water conservation program and in-plant pretreatment will result in a discharge of only 0.35 MGD and 53,000 pounds per day of dissolved solids. Thus, a net reduction in Amax's loading will occur despite the increase in TDS concentration to 18,000 mg/ℓ[5]. To achieve such flow reductions, air coolers have replaced cooling water uses within the plant.

The projected composition of Amax's effluent upon completion of the pretreatment program is depicted as the following:

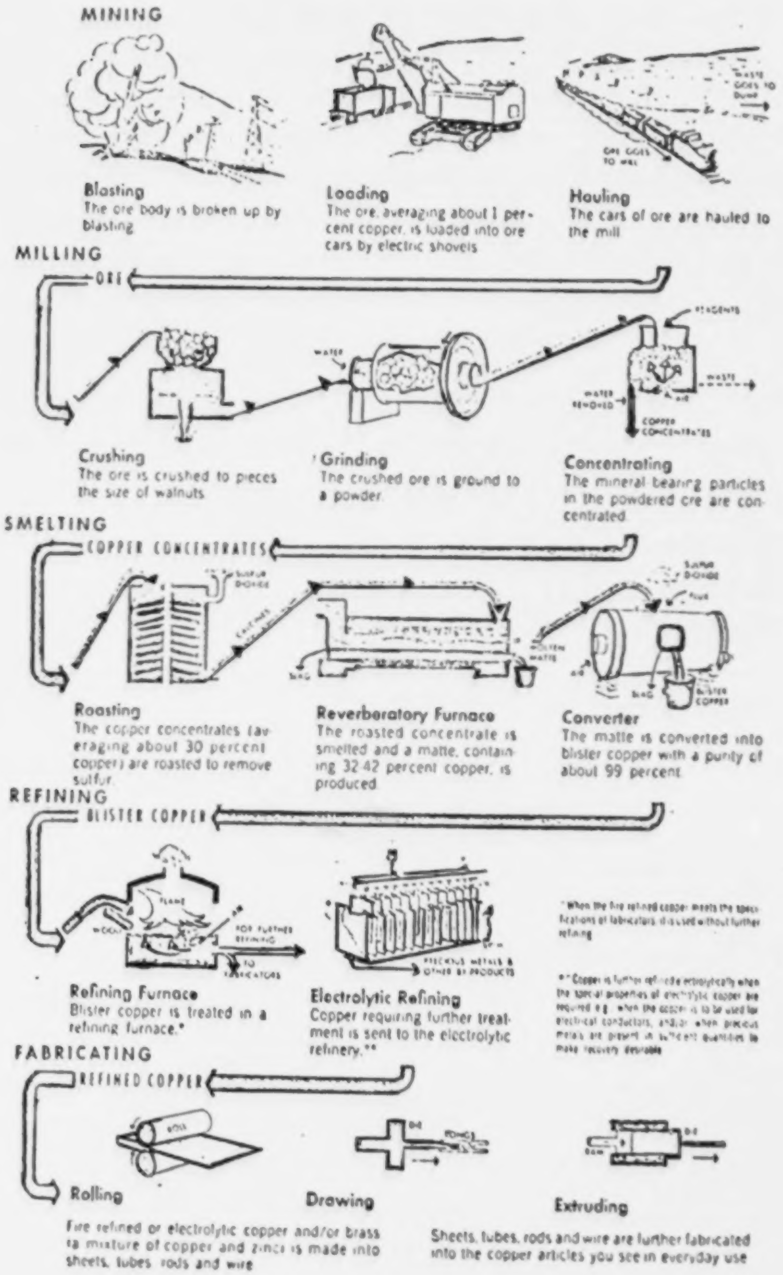
Constituent	Concentration (mg/ℓ[5])
Chlorides	230
Calcium	550
Magnesium	2,500
Sulfate	11,500
Other ions	3,200

The major concentration of TDS appears to be associated with sulfates which are generated during the leaching process. It appears that the TDS contribution is generated during the processing of zinc.

3.2.3 Cerro Copper Products

Cerro is a producer of electrolytic copper and copper tubing products. These are usually the final steps in processing copper as shown in Figure 3-3. Electrolytic refining produces a high purity copper by immersing copper in a dilute solution of sulfuric acid and copper sulfate and creating an electrolytic cell. The TDS contribution of Cerro's can be attributed to a bleed off stream of electrolytic solution and cooling water contributions.

The total loading of 11,000 pounds per day of TDS is only 1.4% of the Village discharge and thus appears to be a minor contribution.


MINING
WASTE GOES TO DUMP
ORE GOES TO MILL
MILLING
ORE
WATER
REAGENTS
WASTE
WATER REMOVED
AIR
COPPER CONCENTRATES
SMELTING
COPPER CONCENTRATES
SULFUR DIOXIDE
CALCINES
SLAG
MOLTEN MATTE
SULFUR DIOXIDE
FLUX
AIR
SLAG
BLISTER COPPER
REFINING
BLISTER COPPER
FLAME
FOR FURTHER REFINING
TO FABRICATORS
PRECIOUS METALS & OTHER BY PRODUCTS
FABRICATING
REFINED COPPER
ROLL
DIE
RAM
DIE

Blasting
The ore body is broken up by blasting

Loading
The ore, averaging about 1 percent copper, is loaded into ore cars by electric shovels

Hauling
The cars of ore are hauled to the mill

Crushing
The ore is crushed to pieces the size of walnuts

Grinding
The crushed ore is ground to a powder.

Concentrating
The mineral bearing particles in the powdered ore are concentrated.

Roasting
The copper concentrates (averaging about 30 percent copper) are roasted to remove sulfur.

Reverberatory Furnace
The roasted concentrate is smelted and a matte, containing 32-42 percent copper, is produced.

Converter
The matte is converted into blister copper with a purity of about 99 percent.

Refining Furnace
Blister copper is treated in a refining furnace.*

Electrolytic Refining
Copper requiring further treatment is sent to the electrolytic refinery.**

* When the fire refined copper meets the specifications of fabricators, it is used without further refining.

** Copper is further refined electrolytically when the special properties of electrolytic copper are required e.g., when the copper is to be used for electrical conductors, and/or when precious metals are present in sufficient quantities to make recovery desirable.

Rolling

Drawing

Extruding

Fire refined or electrolytic copper and/or brass (a mixture of copper and zinc) is made into sheets, tubes, rods and wire

Sheets, tubes, rods and wire are further fabricated into the copper articles you see in everyday use

Figure 3-3: BASIC STEPS--COPPER ORE TO FINISHED PRODUCT

Source: U.S. EPA, "Water Pollution Control in the Primary Non Ferrous Metals Industry," 1973.

3.2.4 Midwest Rubber Reclaiming

The Midwest Rubber Reclaiming plant in Sauget is the largest reclaiming plant in the United States. According to information presented in the U.S. Environmental Protection Agency's Development Document for Proposed Effluent Limitations[6] and Economic Analysis[7], two types of reclaiming operations, wet digestion and pan process, are carried on at this plant. The present 2 MGD of process and cooling water discharges will be reduced to 0.05 MGD by October, 1976. The present total dissolved solids load of 470 pounds per day is attributed to the reclaiming process of rubber.

3.2.5 Edwin Cooper, Inc.

Edwin Cooper, Inc. is a privately held firm which produces additives for lubricating oils. Production of these organic chemicals results in 94,324 pounds per day of TDS, the second largest loading.

The composition of these dissolved solids was broken down according to products by Edwin Cooper, and in Table 3-3 the primary constituents are indicated for the two waste streams.

Table 3-3

TDS CHARACTERISTICS OF EDWIN COOPER[8]

	ECI Products (lbs/day)	CAC (lbs/day)
Sulfates	337	350
Chlorides	23,892	44,365
Calcium Ion	Negligible	15,987
Sodium Ions	9,393	Negligible

3.3 Coal Mining Industry

Among the industries which are affected by present total dissolved solids water quality regulations, the coal mining segment is perhaps the most widely impacted. Although coal mines are exempted from the TDS effluent regulations, the coal industry is subject to meeting water quality standards. In 1970, there were, in operation in Illinois, 59 mines at over 65 million tons per year coal production. The majority of mining operations are faced with the problem of controlling dissolved solids and sulfates to meet water quality. Because of the widespread nature of their problem, the Illinois Coal Operators Association have petitioned for a rule change on this issue for their industry. Thus, it is important to describe their problems and alternatives.

3.3.1 Description of the Problem

The primary area of coal mining activity in Illinois is located in the Mt. Vernon Hills physiographic region. These activities are concentrated in the central and southern counties of Illinois. There are primarily two sources of total dissolved solids which occur during the mining activity. Infiltration of precipitation from previously mined and reclaimed land and accumulation of ground water in the active mining area which must be pumped out. This water is typically high in dissolved solids due to the leaching of the disturbed soil. Since the pumpage is discharged to small streams of low volume, it is very difficult to maintain water quality.

In developing the U.S. Environmental Protection Agency's effluent guidelines for coal mines, the average mine drainage characteristics were described for four types of mines. In Table 3-4 the mean, minimum, and maximum values for TDS and sulfates are summarized. The standard deviation of Table 3-4 indicates the wide range of concentrations which appears in coal mine effluents. According to U.S. EPA, this is attributed to the geology of the coal and associated overburden.

Table 3-4

MINE DRAINAGE CHARACTERISTICS CONCENTRATION

Drainage Type	TDS Minimum (mg/ℓ)	TDS Maximum (mg/ℓ)	TDS Mean (mg/ℓ)	Standard Deviation
Underground-Alkaline	418	22,658	2,702	5,034
Surface-Alkaline	152	8,358	2,867	2,037
Surface-Acid	120	8,870	4,060	3,060
Underground-Acid	12	15,572	4,749	3,245

An example of the levels which may be attained in Illinois mine waters was provided by Southwestern Illinois Coal Company. The TDS concentrations, presented in Figure 3-4, are due to pumpage during mining activities with no contributions from gob piles, treatment plants, or other sources which would increase the levels shown. The samples represent those taken over a several month period and are relatively constant in value. Such discharges certainly affect low flow streams, and the concentration of dischargers intensifies the problem. Depending upon the precipitation which increases the stream flow, water quality may or may not be satisfactory.

Samples taken by the IEPA at Galum Creek are presented in Table 3-5. Three mining operations, Amax, Consolidation, and Southwestern Illinois Coal, all have direct discharges to this stream or tributaries of this stream. According to this data, the TDS water quality standard was violated in 36% of the samples at Station 01 and 21% at Station 02. Low stream flow periods, however, provide little or no dilution which contribute to the water quality problem. This information, with regard to water quality and effluent TDS concentrations, is offered to indicate the significance of this problem in Illinois. Although only information regarding Southwestern Illinois Coal

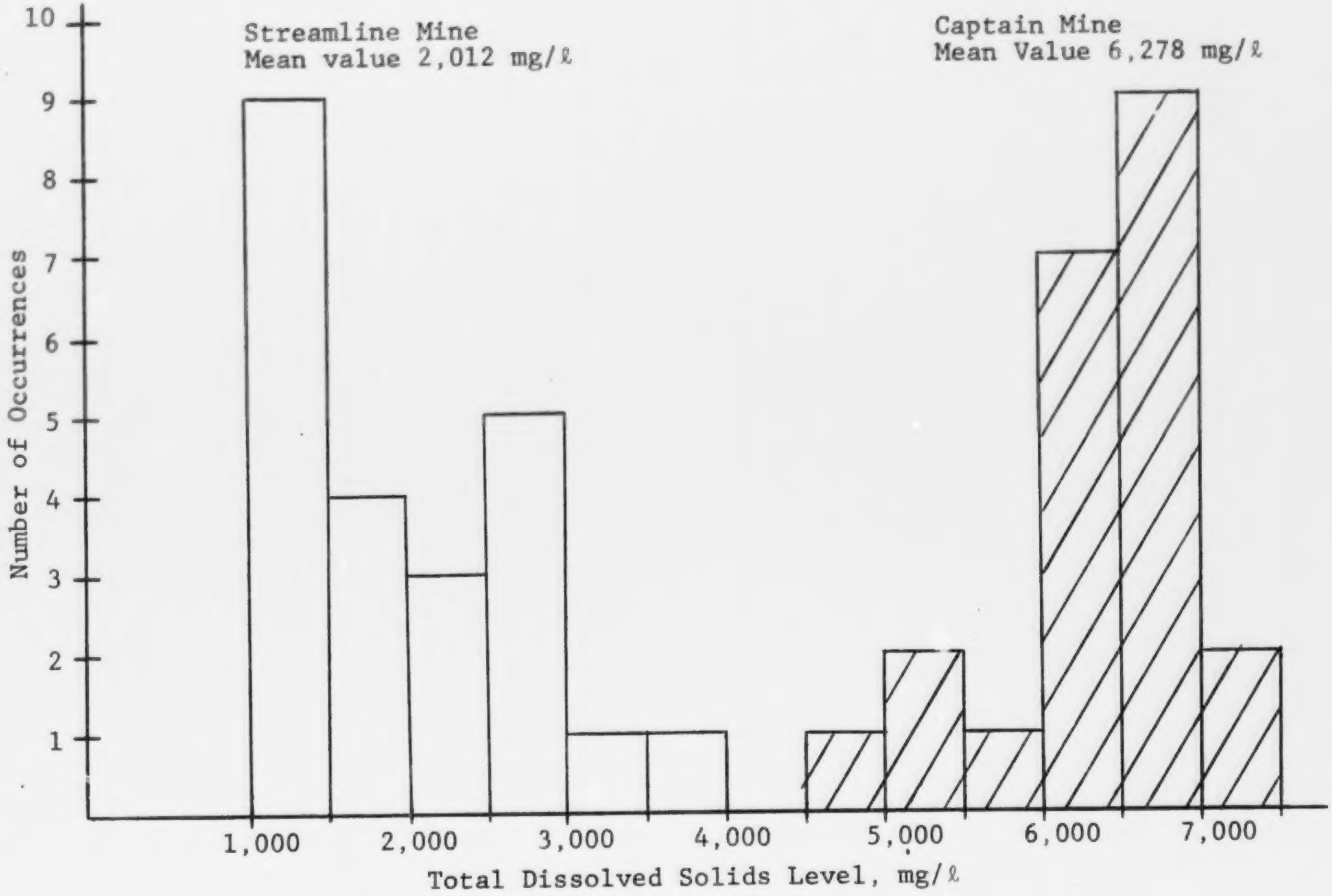


Figure 3-4

FREQUENCY DISTRIBUTION EFFLUENT TOTAL DISSOLVED SOLIDS FROM TWO COAL MINES

Table 3-5

WATER QUALITY OF GALUM CREEK

	NCD 01		NCD 02	
	1974	1975	1974	1975
January	370	320	940	340
February	1,720	-	1,230	390
March	430	410	450	-
April	330	-	-	480
May	1,300	-	1,000	-
June	-	-	-	-
July	3,300	-	-	450
August	3,100	-	2,100	590
September	-	-	-	920
October	-	-	-	430
November	-	-	-	-
December	670	310	820	550

was presented, the water quality problem typically occurs in the coal mining industry as supported by the U.S. EPA data.

3.4 Municipal Water Supplies

There are currently 150 municipalities in Illinois that utilize zeolite softeners for upgrading the quality of their potable water supplies. All of these municipalities utilize well water for their raw water source. Zeolite softeners are typically used by small towns (less than 1 million gallons per day) because of the simplicity in operation. Larger municipalities apply a lime softening process, which requires considerably more man power and a higher operator skill level than the zeolite softeners.

Regeneration of the zeolite filters results in a concentrated salt stream that is either discharged to the municipal waste treatment plant or discharged directly into a receiving stream. The direct dischargers of brine wastes not only exceed the add 750 mg/ℓ TDS standard, but also 3500 mg/ℓ TDS. To date, the IEPA has encouraged the zeolite users to discharge into the city sewers so that the waste is diluted. Where sanitary sewers are not available, the choices remaining for the zeolite users are indeed limited. The IEPA has suggested to each of the zeolite softening plants to remove the brine waste from their effluents, although no enforcement action has been undertaken by IEPA. The municipalities have basically three choices; cease softening altogether, convert to lime softening at a higher cost, or haul the waste brine stream by truck to the closest waste water treatment plant. If the water treatment plants cease softening altogether, most homes will install their own water softener system. Home water softeners are less efficient than the commercial zeolite softeners, thus more pounds of TDS will ultimately be added to the environment from this option. Discharging the regenerative brine stream into the sanitary sewer (either directly or hauled to the sewage treatment plant), has no bearing on the total pounds of TDS added from each potable water plant, although this approach consumes more energy than direct discharge.

3.5 Miscellaneous Affected Dischargers

In reviewing the IEPA effluent monitoring records for 1974-75, all waste water sources with greater than 1,000 mg/ℓ total dissolved solids were identified. These dischargers are categorized in Table 3-6 according to SIC code and level of TDS in the effluent. Eight sources reported concentrations exceeding 3500 mg/ℓ; two municipalities, two chemical companies, one metal finishing operation, one stone quarry, and two miscellaneous dischargers were included. The dischargers between 1000 mg/ℓ to 3500 mg/ℓ may or may not be in violation of the law, depending on the following conditions: intake water TDS level, amount of water recycle, and interpretation of the standard. No attempt was made to ascertain which of the dischargers included in Table 3-6 were in violation. In discussing the TDS standard with various dischargers in the state, several interpretations of the law were evident. Some dischargers stated that because they recycle a portion of their cooling water, the IEPA applied the 3500 mg/ℓ standard, while others said only the TDS increase due to evaporative cooling was utilized by the IEPA in computing the allowable TDS increase above the 'add 750 mg/ℓ' standard. A clear definition of the law is needed before the discharge violators in the 1000-3500 mg/ℓ range can be properly identified.

Table 3-7 identifies those dischargers who exceeded 3500 mg/ℓ both in 1973-74 and 1975, according to IEPA data. Many of these dischargers, along with some of the dischargers between 1000 mg/ℓ to 3500 mg/ℓ, must also seek relief from the current TDS standard.

In addition to the coal companies and potable water plants that are currently out of compliance, there are other industrial groups who must seek relief. Chemical companies, in general, find

Table 3-6

SUMMARY OF DISCHARGERS WITH MAXIMUM TDS LEVELS GREATER THAN 1000 mg/ℓ

		Number of Dischargers with TDS Concentrations (mg/ℓ)					
SIC	Industry Type	1000-1250	1250-1500	1500-2000	2000-2500	2500-3500	> 3500
--	Municipalities	35	23	13	4	1	2
20	Foods	5	-	-	2	1	-
26	Paper Products	-	-	-	1	-	-
28	Chemicals	3	3	1	2	4	2
29	Petroleum Products	1	-	4	-	-	-
32	Stone & Glass	-	-	-	-	-	1
34	Metal Finishing	1	-	-	-	-	1
35	Metal Fabrication	1	-	2	-	-	-
49		3	6	-	-	-	-
--	Miscellaneous	12	4	3	4	3	2
	TOTAL	61	36	23	13	9	8

(Village of Sauget not included.)

Source: IEPA Monitoring Data, 1974-75.

Table 3-7

DISCHARGERS OUT OF COMPLIANCE

Firms in 1974-1975 Over 3,500 mg/ℓ TDS	Firms in 1973-1974 Over 3,500 mg/ℓ TDS
Carus Chemical	Carus Chemical
Livingston Nursing Home	Kerr McGee
Allied Chemical (subsurface)	Skelly Oil
Illinois Tollway Building	Vandalin STW
Taylorville S.D.	Roxana STW
Park City South, Inc.	American Nickeloid
Philadelphia Quartz	Lacon STW
Woodstock Die Casting	B. F. Goodrich
	Rexene Chemical
	Glidden Durkee

Source: IEPA Monitoring Data

it difficult to comply with the 'add 750 mg/ℓ' TDS standard. For example, B.F. Goodrich presented testimony at the regulatory hearings on TDS regarding their inability to comply with the existing TDS standards. From Table 3-7, Carus Chemical, Allied Chemical, and Rexene Chemical also apparently do not meet the TDS standards.

Much of the electric utility industry also is out-of-compliance with the TDS regulations. The power plants utilize zeolite ion exchange softeners for their boiler feed water. Regeneration of the softeners results in a concentrated brine stream, similar to the small potable water plants. Although this brine stream is small compared to the quantity of cooling water utilized at each power station, compliance is required prior to dilution with this cooling water. Commonwealth Edison is currently completing the final engineering for switching regeneration acids, from H_2SO_4 to HCl at their fossil fuel stations, which reduces the quantity of TDS in the regenerative stream. By switching acids, the fossil fuel stations will be close to complying with the 'add 750 mg/ℓ' standard, although some will probably still be in violation. At the nuclear plants HCl cannot be used because of the metallurgical problems with stainless steel and HCl. No viable alternative has been presented for compliance at the nuclear stations. A rule change will probably be sought for the nuclear stations if their respective compliance programs are rejected by either the IEPA or the U.S. EPA because of the TDS violation.

Thus, there are a number of individual dischargers in violation of the TDS regulations, as well as several industrial groups. While a rule change for TDS on the Mississippi River is under consideration, it is important to identify the other violators in the state. If a specific rule change for the Mississippi River, or for just the Village of Sauget is granted, several other petitions for TDS rule change may occur.

Chapter 4

DELINEATION OF EFFLUENT AND WATER QUALITY LEVELS OF TOTAL DISSOLVED SOLIDS

In evaluating the impact of a rule change, it is important to assess not only the existing effluent situation but also the water quality conditions within the state. Because dissolved solids are a natural occurrence in streams, the contributions of point and non-point sources should also be distinguished.

In this section, the existing stream concentrations, historic trends in water quality, and seasonal variations are discussed. Total dissolved solids (TDS) are monitored by the Illinois Environmental Protection Agency (IEPA) and Illinois State Water Survey, and their information has provided the best explanation of the status of TDS in Illinois waters. Special mention is made of the water quality in the Illinois and Mississippi Rivers, which have been emphasized during the regulatory hearings.

Although water quality problem areas are identified and the probable reasons for such difficulties are offered, the actual effects of point and non-point sources are not quantified until Chapter 5. Both contributions are important in determining the future trends in water quality with respect to total dissolved solids.

4.1 Regional Water Quality in Illinois Streams

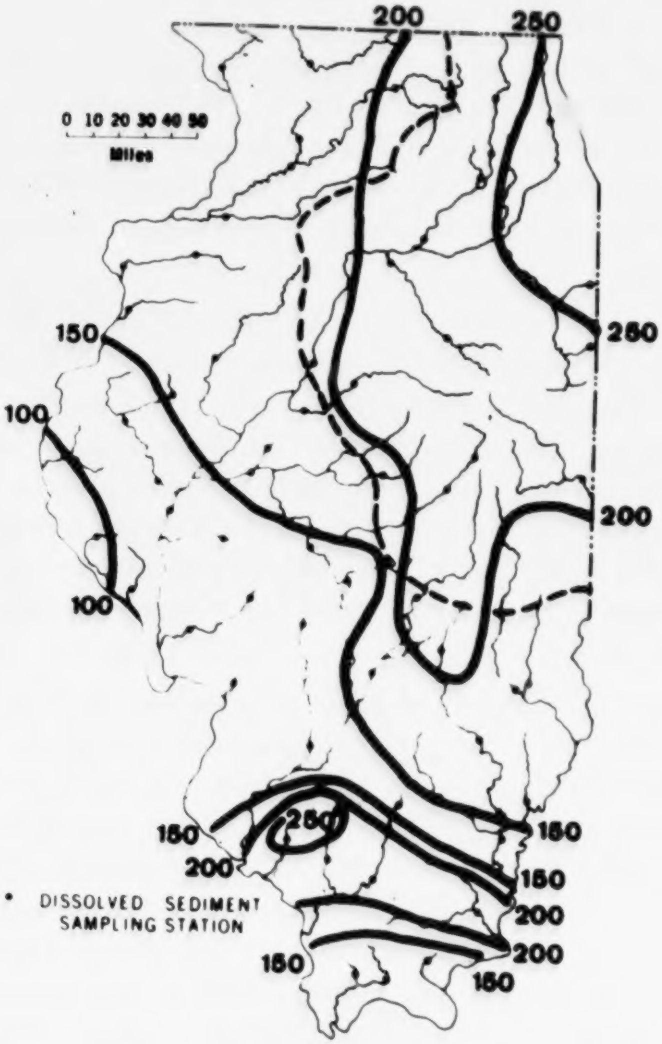
The water quality criteria for Illinois streams vary according to the usage of the water in the stream. General stream standards apply to all waters in the state to protect aquatic life. Public water supplies and food processing waters require more stringent limitations for health and aesthetic purposes. The applicable total dissolved solids levels according to these criteria are the following:

Water Use	Total Dissolved Solids, mg/ℓ	Sulfates, mg/ℓ	Chloride, mg/ℓ
General Stream	1,000	500	500
Public Water Supply & Food Processing Waters	500	250	250
Secondary Contact	-	-	-

A state-wide weighted average TDS concentration of 303 mg/ℓ was reported in a recent study by Flemal and Nienkerk[9]. This study found that total dissolved solids levels in Illinois streams are consistent by regional area. Figure 4-1 shows the existing regional characteristics with respect to dissolved solids loadings. It is interesting to note that Flemal and Nienkerk observed no such regional pattern for some specific compounds, such as potassium, ammonium, and phosphate, while other parameters, including TDS, sodium, carbonate, and hardness, showed strong regional tendencies.

In Figure 4-1, there is a high TDS loading in northeastern Illinois and near southern Illinois. These trends are attributed, according to Flemal and Nienkerk[9], to geological factors and regional point source contribution. The contour in the northeast section which shows high TDS levels closely follows the boundary between younger and older glacial drift areas. The younger areas may leach considerably larger volumes of mineral material which would substantiate the higher levels reported. In the southern part of Illinois, the high TDS belt indicated corresponds to the major surface mining area of the state according to Flemal and Nienkerk.

Based upon the regional TDS patterns observed, one would anticipate that violations of the TDS water quality standards occur in the northeastern and southern part of the state. This is indeed where the majority of violations in the general stream TDS standard (1,000 mg/ℓ) have been reported. The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• DISSOLVED SEDIMENT SAMPLING STATION

Figure 4-1 LONG-TERM YIELD OF TOTAL DISSOLVED SOLIDS (tons/sq mi/yr)

Source: Flemal & Nienkerk, 1976.

magnitude of the water quality violations are categorized in Table 4-1 according to county. A total of 152 of the 10,600 samples collected in 1974-75, or 1.4% of the samples, were reported above 1,000 mg/ℓ. Of the 545 monitoring stations on Illinois waterways, 77 had one or more samples above the 1,000 mg/ℓ level (or 14% of the stations). However, this included 47 stations which were located in secondary contact waters.

Of the 77 stations with TDS levels above 1000 mg/ℓ 21 were in Dupage and 17 in Cook County. This is attributed to the effects of urbanization as well as geological aspects of this area. Saline and Randolph Counties, in which mining activities occur, represent other areas of water quality concern. Fifteen stations reported dissolved minerals stream concentrations above 1,750 mg/ℓ, with a maximum reported value of 3,300 mg/ℓ; however, the majority of the values were between 1,000 and 1,250 mg/ℓ.

River basin areas were also examined for TDS levels above 1,000 mg/ℓ. Table 4-2, which presents the river basins with high water quality levels based upon the 1975 IEPA monitoring data, demonstrates that the regional TDS patterns can be observed by the location of the affected rivers. The Des Plaines River in northeastern Illinois and the Saline and Big Muddy Rivers, which run through the surface mining areas, have the greatest number of stations with TDS levels exceeding 1000 mg/ℓ. Regional water quality analyses thus indicate the areas of concern within Illinois.

4.2 Seasonal Variations in Water Quality

Seasonal variations in TDS levels have been attributed to two phenomena, low flow periods and winter run-off in urban areas. Examples of these occurrences are described to verify their importance.

The Des Plaines River, which flows through the metropolitan Chicago area, has the most water quality stations violations of any basin. Approximately 50 miles of this river have periodic

Table 4-1

WATER QUALITY OF ILLINOIS STREAMS

Planning Area	County	Number of Water Quality Stations with Maximum Reported TDS Level:				
		1,000-1,250 mg/ℓ	1,250-1,500 mg/ℓ	1,500-1,750 mg/ℓ	1,750+ mg/ℓ	Total
1	Ogle	1	--	--	--	1
2	Cook	5	5	4	3	17
	DuPage	17	3	1	--	21
	Grundy	1	--	--	--	1
	Lake	4	1	--	--	5
	Will	5	--	--	--	5
6	Fayette	--	--	--	1	1
	Marion	1	--	--	--	1
	Monroe	1	--	--	--	1
	Randolph	--	3	--	2	5
7	Clay	1	--	--	--	1
	Crawford	--	--	--	1	1
8	Gallatin	--	--	1	1	2
	Hamilton	1	--	--	--	1
	Jackson	--	--	1	2	3
	Perry	--	--	2	--	2
	Pope	1	--	--	--	1
	Saline	--	1	--	5	6
	Williamson	--	2	--	--	2
	Total	38	15	9	15	77

Source: IEPA 1975 Monitoring Data

Table 4-2
RIVER BASINS WITH HIGH TDS LEVELS

River Basin	Number of Stations with TDS>1000 mg/ℓ	Maximum TDS (mg/ℓ) for Samples Taken
Saline	11	3,300
Little Wabash	1	1,000
Illinois	1	1,000
Des Plaines (G)	30*	1,590
(H)	17*	3,760
Mississippi (South)	4	2,000
Big Muddy	7	1,740
Kaskaskia	4	2,100
Lake Michigan	1	1,010
Rock River	1	1,000
Total	77	

* These stations are located in secondary contact waters.

TDS levels greater than 1,000 mg/ℓ. These violations have occurred primarily in the months of January and February, when salting run-off from the roads takes place. In the case of the smaller tributaries to the Des Plaines, low flow periods, such as August and September, also resulted in high total dissolved solids. These conclusions are based on the time period in which the violations occurred. Figure 4-2 illustrates the seasonal TDS trend in the Des Plaines River, and Figure 4-3 shows that of the West Branch of the DuPage River as related to flow. The highest sample taken by the IEPA at Station G-03 of the Des Plaines River occurred in January. It should be noted that other Des Plaines stations also reported similar high values for the same time period. Such a result implies that salting of urban roadways may have been carried off into the streams during this short period.

Tributaries such as the West Branch of the DuPage River, which have very low flows in the summer, experience higher concentrations during these periods. Figure 4-3 shows that the highest reported TDS values occurred in September, which is also the lowest flow month for the West Branch of the DuPage River.

Other areas of water quality violations, such as the Saline River, are also closely related to low flow periods and soil composition. The Saline River water quality was monitored by IEPA, and the seasonal aspects of the violations are clearly indicated in Table 4-3. The months of July, August, and September represent the time interval in which violations most frequently occur.

The regional and seasonal variation in TDS concentrations have been described. Another aspect of importance in assessing the TDS regulations is the historical trend in TDS levels, which is discussed in the next section.

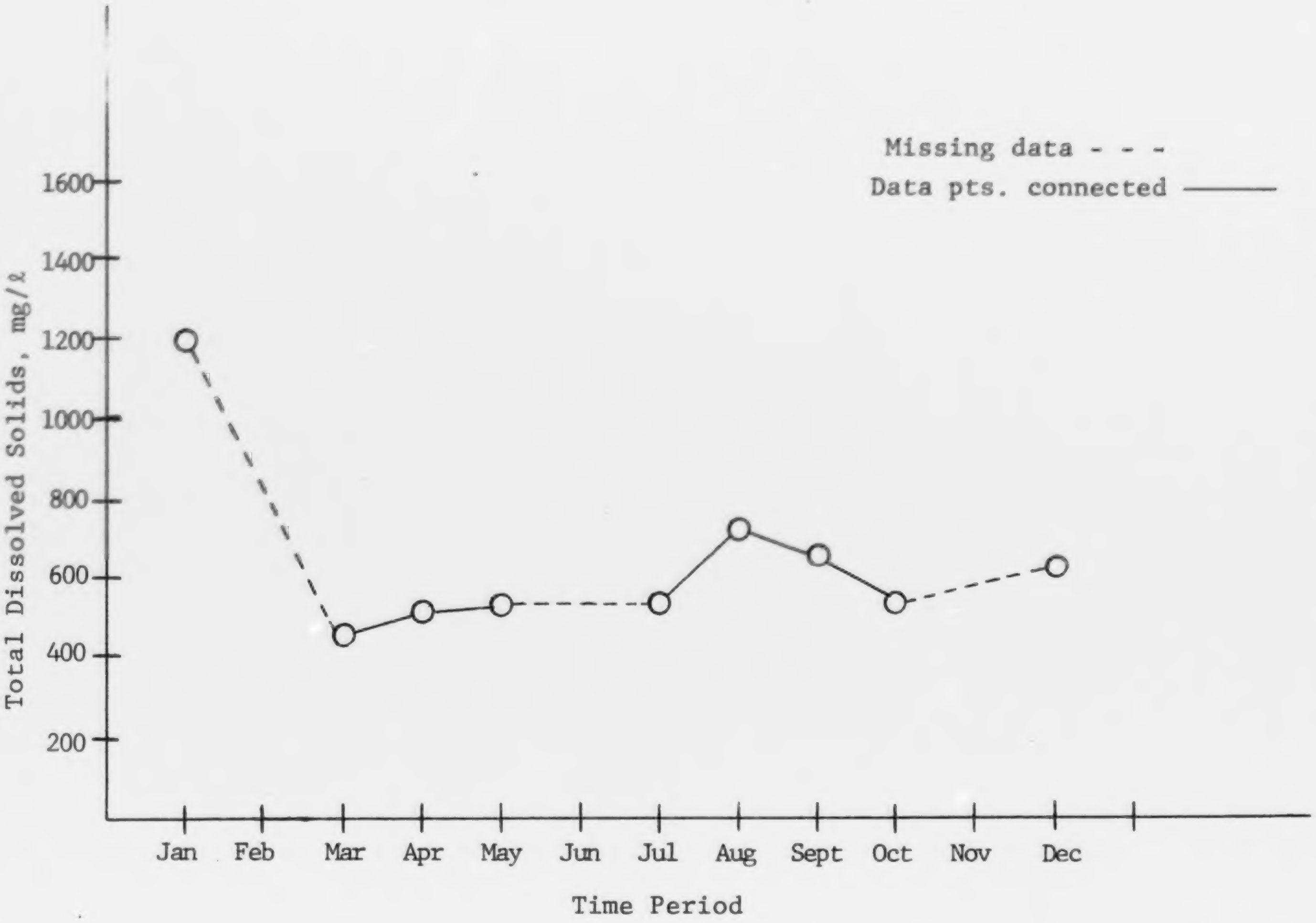

Figure 4-2 SEASONAL VARIATION IN TDS IN THE DES PLAINES RIVER*

* 1975 Values, Station G-03

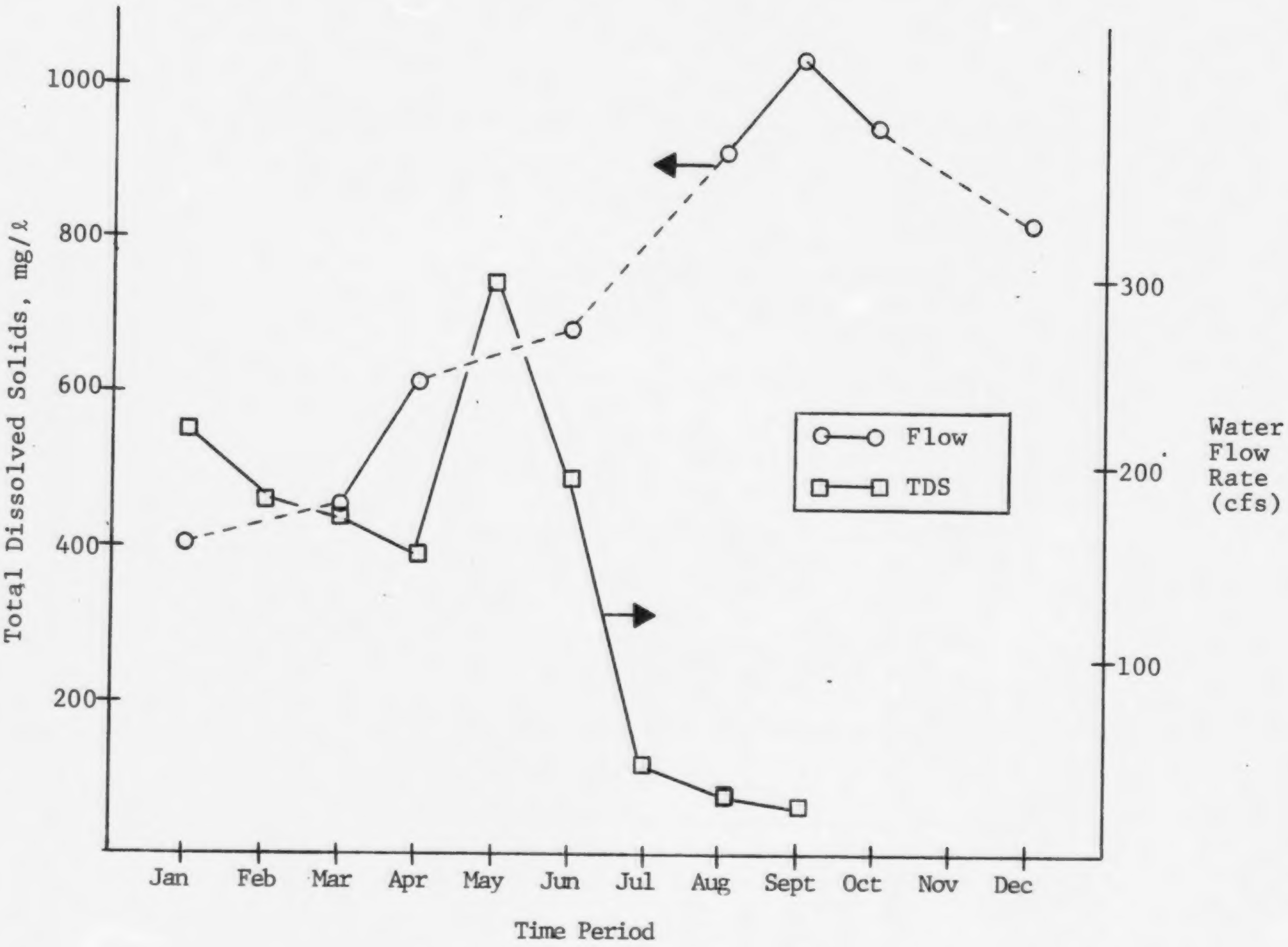

Figure 4-3 SEASONAL VARIATION IN TDS IN THE DUPAGE RIVER-WEST BRANCH (1974 Values)

Data from IEPA and
Water Resources Data for Illinois

Table 4-3

TDS LEVELS IN THE SALINE RIVER*

Month	TDS Levels, mg/ℓ					
	Station AT 02		Station AT 04		Station AT 05	
	1974	1975	1974	1975	1974	1975
January	200	220	--	360	--	--
February	210	290	250	650	330	330
March	230	212	390	--	320	160, 212
April	260	180	360	170	420	260
May	290	390	350	--	400	430, 490
June	250	500	480	540, 746	410	--
July	290	360	680	--	1,800	--
August	310	270	1,600	--	--	720
September	400	290	--	210	880	870
October	420	270	520	--	670	340
November	--	360	420	810	440	830
December	510	330	370	350	480	540

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* The concentrations represent single sample values not monthly averages.

4.3 Water Quality Trends

Effluent regulations have been promulgated at both the state and federal levels in order to protect the aquatic environment. Historical trends in water quality indicate a general deterioration during the 1950's and 1960's. By reviewing the historical trend of dissolved solids concentration in Illinois waterways, insight into the need for regulating dischargers of TDS can be obtained.

Flemal and Nienkerk[10] calculated the weighted average TDS concentrations at various sampling stations. Twelve sampling stations where data were available for more than one period are presented in Table 4-4. An increase in the TDS concentration was observed at nearly every station, with the average increase of 7% per five-year period or 1.4% per year. The Spoon River Station had the greatest increase, 48% in 10 years, of the stations investigated.

It is difficult to verify the existence of trends utilizing, in most cases, only two time periods. However, the large number of rivers exhibiting increases over the two periods strongly suggests there has been, and perhaps still is, a trend toward increasing TDS levels in Illinois waterways. A closer examination of the two rivers of major concern in regulatory hearing R75-6 is provided in the next section.

4.4 Water Quality of the Mississippi and Illinois Rivers

The village of Sauget, located on the Mississippi River, has petitioned for an exemption to the TDS effluent standard. B. F. Goodrich, which operates an industrial plant on the Illinois River, is also seeking a TDS exemption to include dischargers on the Illinois River, although to date they have not submitted a formal request.

As major watercourses, each has a large flow, receives drainage from urban and rural areas, and has been monitored for many years. By analyzing water quality data from 1955 through

Table 4-4

TRENDS IN TDS CONCENTRATIONS IN VARIOUS ILLINOIS RIVERS

Stream	Station Number	Sampling Period[1]	Weighted Average TDS Concentration, mg/ℓ	% Increase (Decrease) Per 5-Year Period
Illinois River at Meredosia	104	3	314	
		4	360	+ 15
		5	379	+ 5
Kaskaskia River at New Athens	81	1	193	
		3	216	+ 6
		4	216	0
Kaskaskia River at Shelbyville	105	3	297	
		4	270	- (9)
		5	315	+ 17
Elkhorn Creek near Penrose	22	4	306	
		5	311	+ 2
Embarras River near Comargo	209	4	242	
		5	277	+ 14
Fox River at Algonquin	2	3	389	
		5	400	+ 1
Rock River at Como	23	3	323	
		4	335	+ 4
Seven Mile Creek near Mt. Vernon	207	4	189	
		5	197	+ 4
Skillet Fork at Wayne City	88	1	183	
		3	188	+ 1
Spoon River at London Mills	49	1	228	
		3	339	+ 24
Vermilion River at Lowell	39	3	314	
		5	388	+ 12
Wolf Creek near Beecher City	201	4	162	
		5	174	+ 7

[1] Sample Period:
1 = 1945-1950
2 = 1950-1956
3 = 1956-1961
4 = 1961-1966
5 = 1966-1971

Source: "Regional Distribution of the Major Dissolved Solids in the Streams of Illinois"

1974, the historical trend of the mean TDS concentration has been ascertained. Figures 4-4 and 4-5 depict these trends with time. The maximum, minimum, and mean TDS values have been computed to illustrate the possible deviations which occur in any year. A regression analysis of TDS levels from 1955 through 1971 indicates the increasing trend depicted by the least-squares fit is statistically significant*. Or in other words, the progressive growth of the mean is not due to some random variation, but is increasing as a function of time.

The 1972-1974 data was not included in the analysis since a different, less accurate analytical test method was utilized in these years (electrical conductivity, previous years by evaporation). This is indeed unfortunate, since the last three years would have provided insight into how effective the TDS regulations have been in curbing the increasing TDS trend.

The least-squares fit indicates the TDS levels are increasing at a rate of 1.6 mg/ℓ and 4.9 mg/ℓ for the Mississippi and Illinois Rivers, respectively. Both rivers average TDS concentrations below 500 mg/ℓ, which is the food processing standard; however, maximum values exceeding this water quality standard have on occasion occurred in the Illinois River. At Meredosia in 1971, a maximum TDS level of 580 mg/ℓ was recorded, the highest level reported for the 20-year period. The maximum reported TDS concentration in the Mississippi at Chester also occurred in 1971; a value of 447 mg/ℓ was measured in that year.

Thus, a least-squares analysis of data on the Illinois and Mississippi Rivers supports the findings of Flemal and Nienkerk described in the previous section. That is, there

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* Description of the Statistics: Utilizing a simple regression technique, the coefficient of the time factor with respect to the TDS mean concentration was determined. If, indeed, there has been no pattern to historical mean TDS levels, the coefficient of the time factor would not be discernable from "0". Using the t-statistic, the coefficient was tested and found to be significant at the 95% confidence interval. The actual t-values were 7.7 and 34.8 for the Mississippi and Illinois Rivers, respectively.

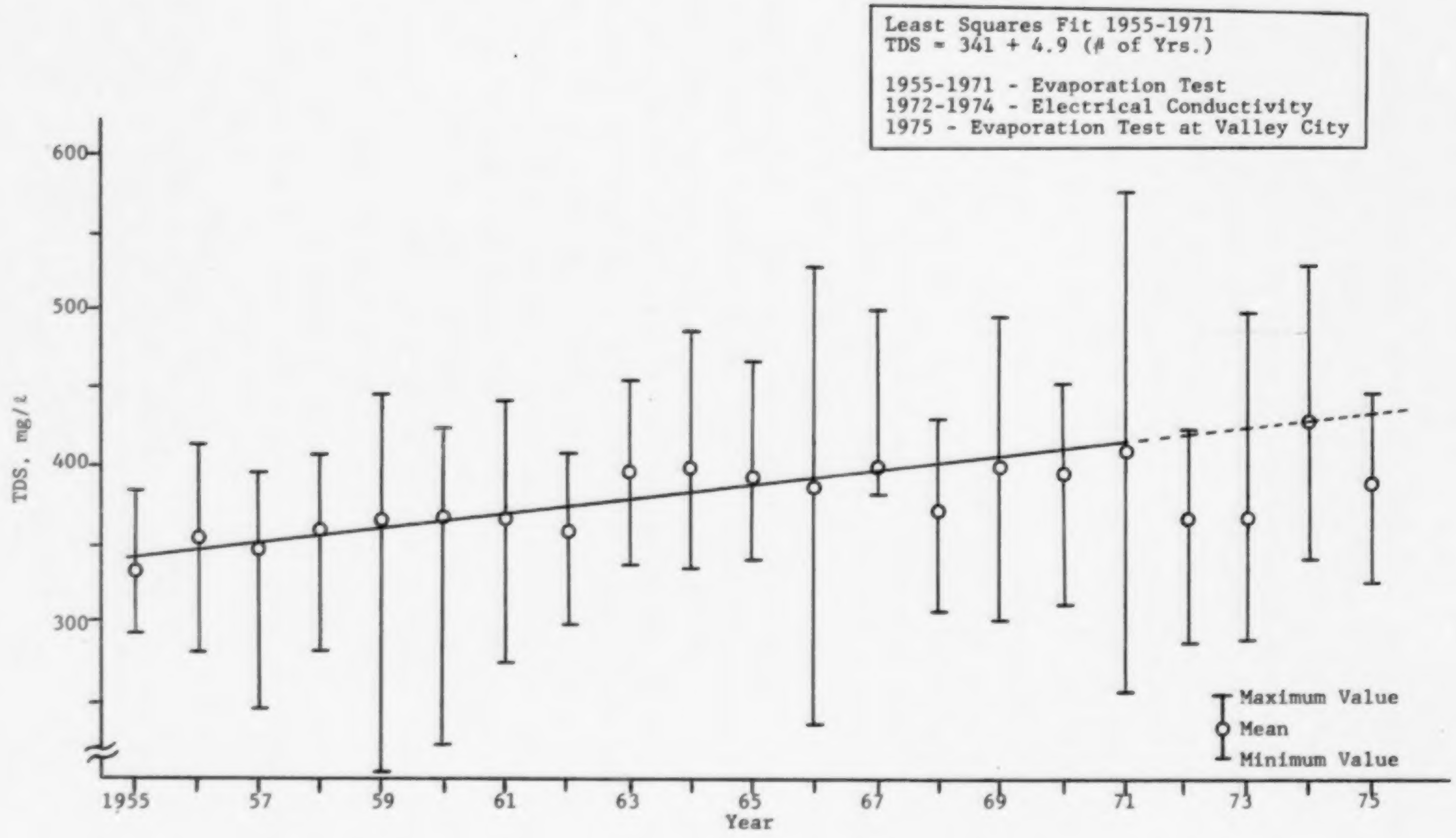

Figure 4-4 - ANNUAL TDS LEVELS IN ILLINOIS RIVER AT MEREDOSIA

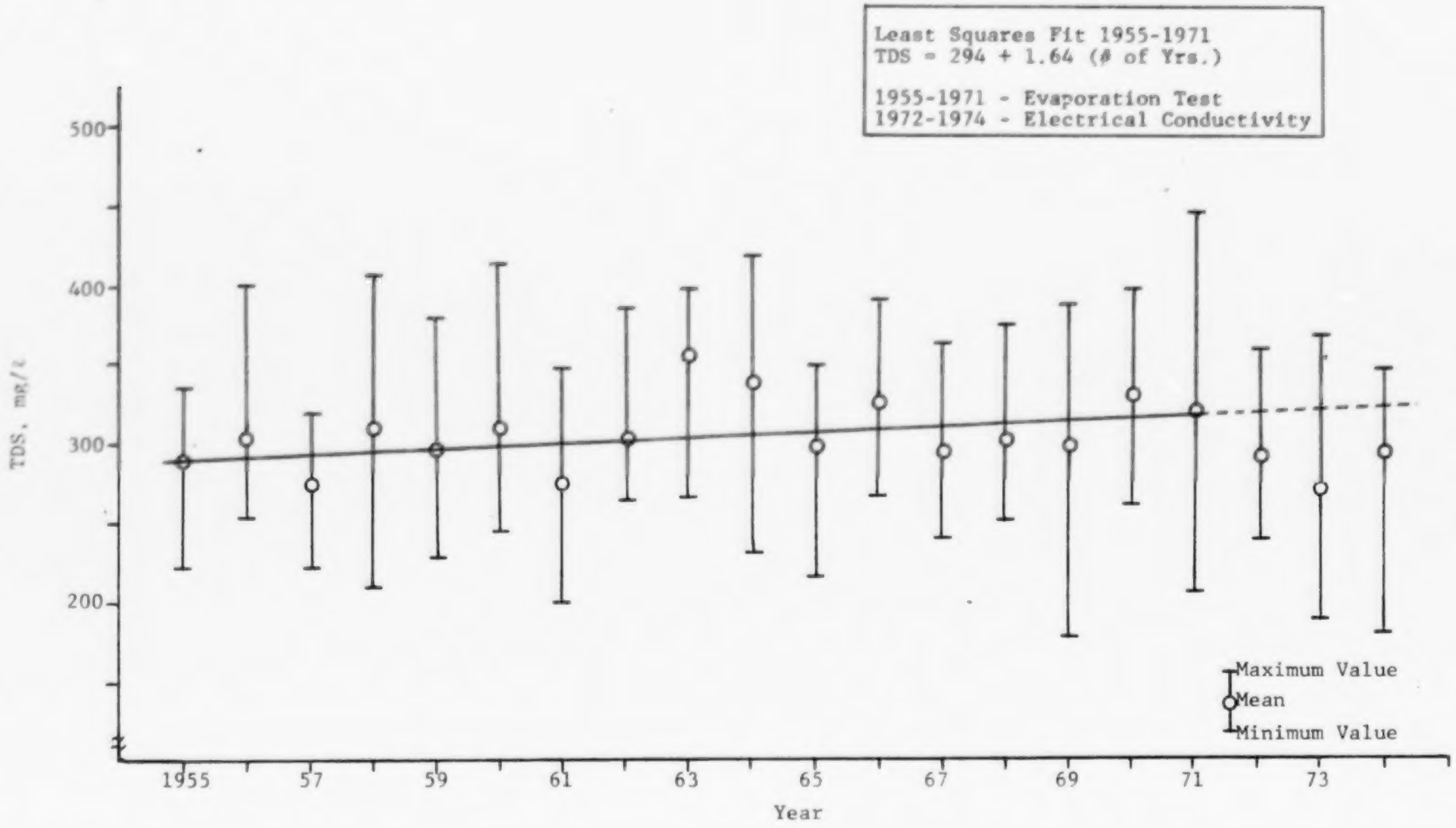

Figure 4-5 - ANNUAL TDS LEVEL IN MISSISSIPPI RIVER AT CHESTER

has been a general increasing trend in water quality TDS levels in Illinois, at least up until 1971.

4.5 Projected TDS Levels

Projection of future water quality levels is a very difficult task because of the large number of variables involved. If industrial dischargers are a major source of TDS loadings in Illinois waterways, then the present effluent regulations should result in lower TDS water quality levels. The change in the TDS analytical methods adopted by IEPA precludes drawing any inferences about the effectiveness of the effluent regulation until several more years of data are collected.

The increasing TDS trend discussed in the previous section contrasts with the general trend for the major United States waterways. The U.S. EPA[11] reported that of the 22 waterways across the country investigated from 1963-1972, the following trends were observed:

Parameter	Number of Reaches Analyzed	% of Reaches Improved
TDS (105°C)	28	64
TDS (180°C)	23	61
Chlorides	34	62
Sulfates	33	55

Utilizing these data and other information, the U.S. EPA computer model projected future TDS levels. These projections are shown in Figure 4-6. The uncontrolled discharge rate is projected to increase through 1985, while a continuation of 1971 abatement programs will result in a leveling off of the TDS discharge rate by 1980 at 130% of the 1971 rate. Such projections are unique since there are no federal TDS effluent standards, and Illinois is the only state that has adopted effluent TDS standards (see Chapter 8). Thus, the difference between "controlled" and "uncontrolled" projections is difficult to understand.

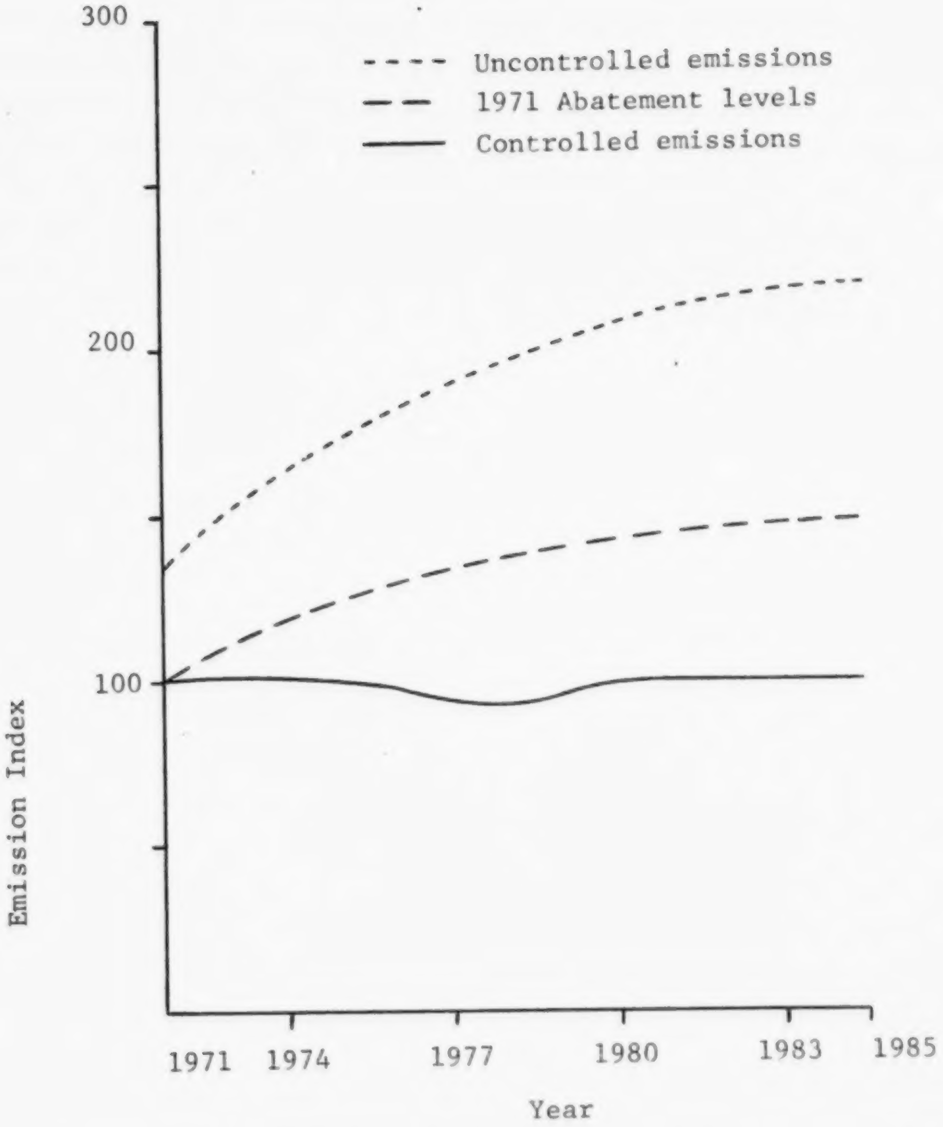

Figure 4-6: PROJECTED UNITED STATES TOTAL TDS LOADING

Source: Council for Environmental Quality-the Fifth Annual Report, Pg. 293, December 1974.

The general increase in TDS levels in Illinois waterways observed over the past 20 years may be sufficient justification for state effluent regulations if the industrial dischargers are a major source of dissolved solids. If the major contribution of TDS is from other sources (i.e., agriculture, storm-water run-off, road de-icing, etc.), effluent TDS standards perhaps should be limited to rivers where high TDS levels exist and to those point source dischargers that are major contributors. The sources and their contribution of dissolved solids in Illinois waterways are described in Chapter 5.

Chapter 5

SOURCES OF TDS IN ILLINOIS

When the effluent standards were originally proposed in Illinois, there was considerable testimony presented which questioned the need for a TDS standard, and especially a standard as low as the original proposed standards. The effluent limitation finally adopted by the Pollution Control Board provided allowances for higher TDS concentrations resulting from water reuse systems, up to a maximum concentration of 3,500 mg/ℓ. The Village of Sauget was able to achieve the 3,500 mg/ℓ level (although it is not clear whether Sauget was allowed 3,500 mg/ℓ TDS in their effluent during this period) until 1973, when a water conservation program was initiated. As a result of this water conservation program, Sauget is currently over the 3,500 mg/ℓ level. With further decreases in effluent flow planned by Sauget, a further increase in the TDS effluent level is anticipated. Thus, Sauget must seek relief from the regulation or install facilities at the treatment plant to remove TDS.

Much of the Village of Sauget's position for a regulatory change is based upon the high cost of treatment compared to the benefits gained. As pointed out in Chapter 3, Sauget is not the only discharger in the state violating the current regulation, and other dischargers (i.e., B. F. Goodrich) could make the same cost/benefit claim as Sauget. Using an individual analysis of costs and benefits is not always a wise or appropriate technique. While one discharger may have a negligible effect on water quality, the aggregate impact of dischargers along a waterway may result in serious water quality degradation.

An important question, which this chapter addresses, is discerning the influence of industrial effluents on the overall TDS levels in Illinois. This is a very difficult issue to resolve, and only a very crude estimate is presented here. However, the results do provide an interesting perspective that should be considered in assessing the current TDS regulations.

5.1 A Previous Study on Illinois Water Quality

Flemal and Nienkerk[9,10] investigated the regional characteristics of TDS in Illinois waterways. As discussed in Chapter 4, these authors found that the weighted average TDS level in Illinois waterways is 303 mg/ℓ, which corresponds to an annual drainage rate of 222 tons of TDS/mi^2/yr. This level is considerably higher than most "natural" streams found in the Midwest, and the authors state that the TDS drainage rate is twice that of the Mississippi River Basin as a whole.

Based on their results, Flemal and Nienkerk believe that the high TDS levels are primarily attributed to non-point sources and regionally homogeneous sources, such as the Chicago area. As a preliminary estimate, the authors state that the TDS contributed by human activities (anthropogenic sources) is between 50 to 67% of the total TDS contribution. Flemal and Nienkerk did not attempt to estimate the quantity originating from various human activities, which is of primary importance in the establishment of TDS effluent standards.

5.2 Mass Balance on TDS Leaving the State of Illinois

An estimate of the magnitude of the TDS contribution received from various sources was considered an important factor in properly describing the status of TDS levels within the state. Thus, a mass balance of TDS in state waters was calculated for the major river basins.

There are seven major rivers that drain 94% of the total land in Illinois. These rivers, and their associated drainage areas, are listed below:

River	Drainage Area, mi^2
Rock	10,800
Illinois	29,000
Kaskaskia	6,000
Big Muddy	2,400
Saline	1,000
Embarras	2,300
Vermillion	1,300
Total	52,800

Utilizing flow and TDS concentration data, the total quantity of TDS (lb/day) can be computed for various stream conditions. Shown in Table 5-1 is the minimum, median, and 90% TDS loadings for the seven rivers. (A detailed discussion of the procedure and data utilized is presented in the Appendix.) The median quantity of TDS leaving the state is 44.1 x 10^6 lb/day, while the range is from 15.2 x 10^6 to greater than 139 x 10^6 lb/day.

Utilizing this median lb/day TDS value, one can attempt to identify the sources and quantify their contribution to TDS levels. The following descriptive list specifies eight major sources:

- Background TDS in Lake Michigan Water

  3,200 cfs of water is withdrawn from Lake Michigan and discharged after use into the Illinois River System.

- Domestic Waste Contribution

  Domestic sewage typically contains 200 mg/ℓ more TDS than does the corresponding potable water supply.

- Municipal Ground Water Supply

  Ground water after use if discharged to surface streams. Approximately 300 MGD of ground waters are used in Illinois by municipalities.

- Industrial Ground Water Supply

  Industries in Illinois lift approximately 260 MGD of ground water which is also discharged to surface waters after use.

Table 5-1

MAJOR RIVERS DRAINING ILLINOIS

River	Drainage Area, mi^2	Flows, cfs				TDS, mg/ℓ			Time Period of TDS Data, and Station
		7-day, 10-yr Low Flow	10% Flow	50% Flow	90% Flow	10% Conc.	50% Conc.	90% Conc.	
Rock	10,800	1,466	1,915	4,256	15,000	295	340	425	1961-1966 at Como
Illinois	29,000	3,600	6,070	13,700	41,000	333	404*	462	1966-1971 at Meredosia
Kaskaskia	6,000	147	205	1,640	15,600	190	340	460	1961-1966 at New Athens
Big Muddy	2,400	36	36	320	5,860	200	400	940	1956-1961 at Murphysboro
Saline	1,000	3	8	140	3,950	233	1,026	1,920	1971 at Ohio River Junction
Embarras	2,300	35	54	708	5,540	250	330	390	1956-1961 at Ste. Marie
Vermillion	1,300	42	47	332	2,175	180	450	710	1958-1965 at Danville
Totals	52,800	5,329	8,335	21,096	89,125				

*Mean value, median value is 413 mg/ℓ

- Road De-Icing

  Illinois currently uses 300,000 ton/year of salt for de-icing, most of which finds its way into the surface waters of the state.

- Irrigation

  Approximately 140 mi^2 of land are irrigated in Illinois.

- Industrial Contribution

  Industrial water use (excluding cooling water) is approximately 1,500 MGD. The estimated contribution, in lb/day, is presented in Table 5-2 for various categories by TDS concentration.

- Storm-Water Runoff

  A major source of TDS is evidenced by the wide difference between the median and 90% TDS loadings shown in Table 5-1.

The Appendix includes a more detailed discussion of each of the above sources and the calculation of their contributions.

Based upon the identified sources of TDS and the estimated contribution from each source, Table 5-3 was prepared. The results indicate that storm-water runoff (urban and rural) contribute approximately 65% of the total pounds of TDS found in the rivers in Illinois. Three sources of industrial contributions are presented in Table 5-3; background from industrial ground water supplies, industrial plants discharging less than 1,000 mg/ℓ, and those plants discharging greater than 1,000 mg/ℓ.

The industrial sector that discharges less than 1,000 mg/ℓ was considered in compliance with the current TDS regulation of 750 mg/ℓ above background. The industrial sector discharging greater than 1,000 mg/ℓ was presumed to be adding the minerals to the water, as opposed to concentrating the minerals through evaporative cooling. This is indeed a harsh assumption, since many of the discharges above 1,000 mg/ℓ TDS are the result of recycling cooling water, thus concentrating the minerals. No attempt was made to identify what fraction of the dischargers above 1,000 mg/ℓ are concentrating the minerals as opposed to adding the minerals found in their effluents. Thus, the 3.1%

Table 5-2

INDUSTRIAL TDS CONTRIBUTION

Industrial Category by TDS Conc.[1], mg/ℓ	Mean TDS, mg/ℓ	Mean TDS Contributed[2], mg/ℓ	% of All Industrial Dischargers	Total Contribution[3], lb/day x 10^{-6}
> 2,000	3,000	2,700	1.4	0.47
1,500-2,000	1,800	1,500	1.4	0.26
1,300-1,500	1,400	1,100	1.4	0.19
1,200-1,300	1,250	950	1.4	0.17
1,000-1,200	1,100	800	2.8	0.28
800-1,000	900	600	12.5	0.94
700- 800	750	450	16.7	0.94
600- 700	650	350	26.4	1.16
500- 600	550	250	36.0	1.13
		Total	100.0	5.54

[1] From Illinois EPA 1975 monitoring data

[2] Mean TDS minus mean background TDS in Illinois, 300 mg/ℓ

[3] Based on total industrial flow of 1,500 MGD (excluding cooling water)

Table 5-3

TDS MASS BALANCE FOR ILLINOIS

Source	Average TDS Discharged to Illinois Waterways, 10^6 lb/day	Percent of Total TDS[1] Loading, %
Background from Lake Michigan	2.85	6.5
Domestic waste contribution	1.90	4.3
Background from municipal ground water	1.25	2.8
Background from industrial ground water	1.08	2.4
Road de-icing	1.64	3.7
Irrigation	0.19	0.4
Industrial contribution		
$<1,000$ mg/ℓ	4.16	9.4
$>1,000$ mg/ℓ	1.38	3.1
Storm-water runoff	28.9	65.5
Total	43.35	98.3

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[1] Average TDS leaving the state via the seven rivers presented in Table 5-1 is 44.1 x 10^6 lb/day.

of the TDS attributed to industrial dischargers with TDS concentrations above 1,000 mg/ℓ is probably an over-estimate of their contribution.

The contribution by those industries discharging more than 1,000 mg/ℓ can be placed into perspective by comparing the 3.1% with other sources.

Several of the sources, including road de-icing, background from Lake Michigan, and domestic waste, contribute more dissolved minerals than does the industrial sector discharging greater than 1,000 mg/ℓ. Storm-water runoff alone contributes more pounds of TDS than all other sources combined. The industrial sector discharging greater than 1,000 mg/ℓ is directly affected by the Illinois TDS effluent regulation, while the regulation has little or no effect on the other sources, which apparently account for 97% of the total TDS loading.

5.3 Significance of the Mass Balance Results

While the estimated contributions of TDS to the waters of Illinois are only crude approximations, they do provide interesting results. If the magnitude of industrial TDS loading is correct, then only a small portion of the total TDS can be satisfactorily controlled through effluent regulations. From Table 5-3, it is apparent man's activities contribute much of the overall TDS found in the rivers of Illinois. Flemal and Nienkerk estimated that man's activities may contribute from 1/2 to 2/3 of the TDS loading. Excluding the storm-water runoff, all of the other sources used in this estimation (which are a result of man's activities) account for 1/3 of the total loading. Much of storm-water runoff can also be attributed to man, such as fallout of atmospheric sulfur, fertilizer loss, and urban storm-water collection and discharge systems. Thus, Table 5-3 supports the conclusions of Flemal and Nienkerk concerning man's influence on the TDS level. However, the industrial dischargers affected by the effluent standard appear to account for only a small part of man's influence.

Chapter 6

ECONOMIC IMPACT ON VILLAGE OF SAUGET

6.1 Options Available to Sauget

The Village of Sauget currently violates the total dissolved solids effluent standard in Illinois. The two alternative actions available to Sauget are first, compliance with the existing regulation or second, passage of a regulatory amendment which would alleviate the need for installation of control equipment. The economic impact upon Sauget depends upon the decision of the Illinois Pollution Control Board regarding their regulatory proposal.

Within this section, the available methods for controlling total dissolved solids are presented. Utilizing the most feasible treatment technology, the associated capital investment and operating costs for the Village of Sauget have been determined. Because each industrial discharger contributes a unique amount of TDS, the costs of treatment must be allocated accordingly among the five. The quantity and type of dissolved solids for each industrial discharger is described and a proportionate cost of TDS treatment is assigned to each.

The impact of increased capital and operating costs on the Village of Sauget, because of TDS treatment, can only be analyzed on a plant by plant basis. The economic responses of firms to increased costs can be described by price, output, and employment changes. There is uncertainty as to the actual microeconomic decision or response, and therefore a range of responses is considered in the economic analysis. By describing the general economic and financial aspects of each plant, the anticipated price, output, and employment responses may be ascertained. The assumptions utilized to obtain these results are specified and recognized as limits to the analysis.

6.2 Control Costs for TDS Removal

The removal of dissolved solids from wastewater streams is an expensive and complex process. Isolation and treatment of the in-plant waste streams with the high TDS levels reduces the volume of water requiring treatment and may be more economical. However, where there are numerous sources of high TDS, treatment of the entire wastewater stream may be more economical. Monsanto investigated the treatment of their individual brine streams and concluded this approach would cost more than treating the entire effluent from the Village[12].

The Village of Sauget hired a consultant to prepare a conceptual design and preliminary cost estimate for bringing the entire effluent into compliance with the 3,500 mg/ℓ TDS Illinois effluent standard. The conceptual treatment design for the Village provided by their consultant is presented in Figure 6-1. The major treatment step is a reverse osmosis unit which reduces the TDS in 4.19 MGD, while concentrating the solids in 1.41 MGD. The reject brine stream contains nearly 3% dissolved solids (29,450 mg/ℓ) and must be disposed of in an environmentally sound manner. The conceptual design utilized deep well injection under the conditions that the geology around the Village was acceptable and that the regulatory agencies (Illinois EPA and U.S. EPA) would approve of such an operation.

These two conditions required in selecting deep well disposal are probably not realistic. The disposal of 1.4 MGD into a deep well could result in extremely large back pressure and a very short life for the well. Regulatory agencies have, in general, discouraged the use of deep well injection and approval in this case is questionable. Because of the uncertainty over the acceptability of deep well disposal, cost estimates for two alternatives were developed.

The first alternative to deep well disposal is a drying of the solids in a multi-effect evaporator, similar to that utilized in desalinization plants. In addition to the large

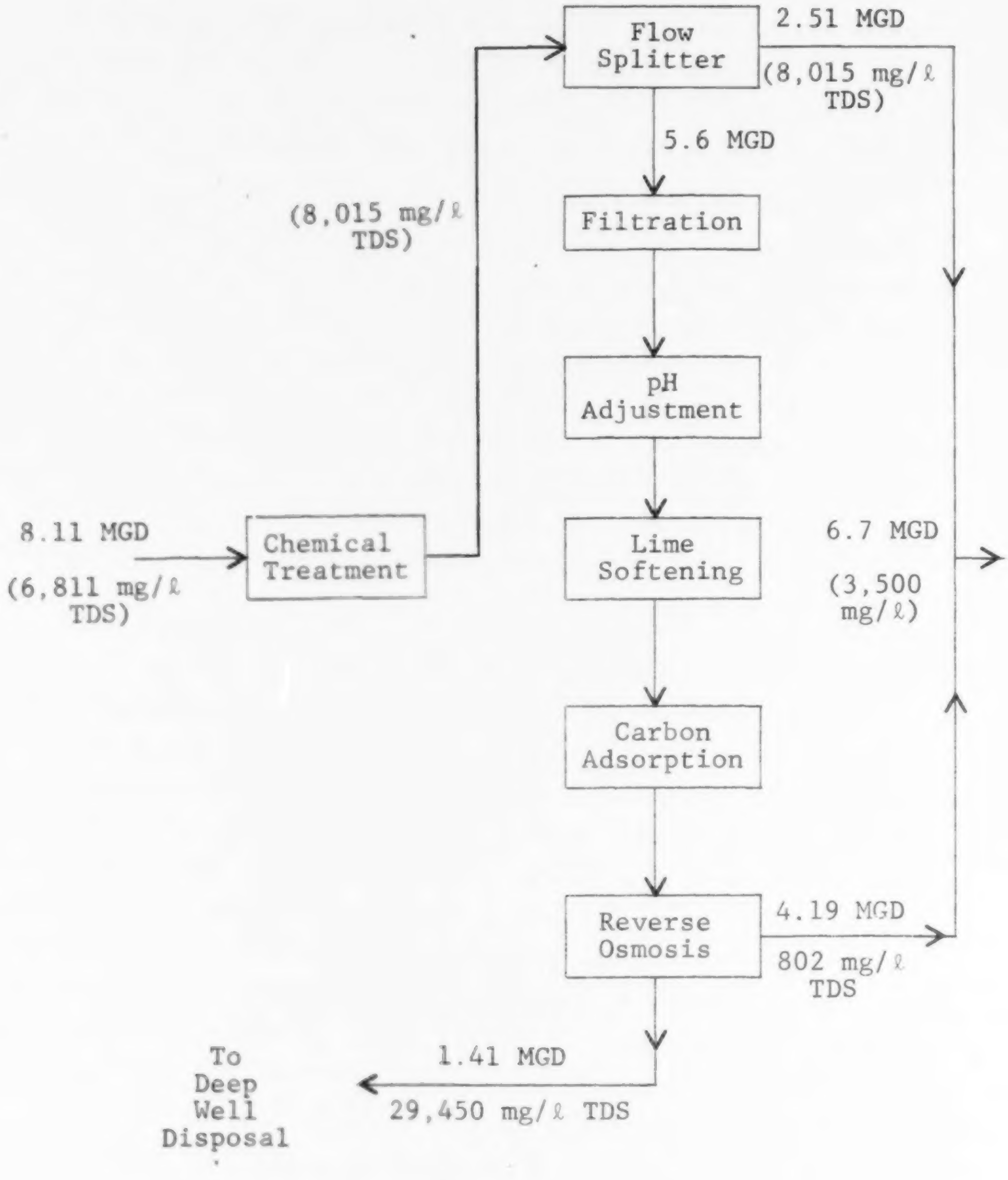

Flow Splitter
2.51 MGD
(8,015 mg/ℓ TDS)
5.6 MGD
Filtration
(8,015 mg/ℓ TDS)
pH Adjustment
8.11 MGD
(6,811 mg/ℓ TDS)
Chemical Treatment
Lime Softening
6.7 MGD
(3,500 mg/ℓ)
Carbon Adsorption
Reverse Osmosis
4.19 MGD
802 mg/ℓ TDS
To Deep Well Disposal
1.41 MGD
29,450 mg/ℓ TDS

Figure 6-1

CONCEPTUAL DESIGN OF PROPOSED SAUGET TREATMENT SYSTEM capital expenditure, fuel consumption, and sludge disposal costs account for an additional $1,880,000 per year. The other alternative, solar evaporation, requires the purchase of 1,000 acres of land. While the capital expenditure for this alternative requires $2,000,000 more than for the multi-effect evaporators, fuel costs are $850,000 per year lower.

A comparison of the capital and annual costs for the three alternatives evaluated is presented in Table 6-1. Additional details on the preparation of each cost estimate are provided in the Appendix to Chapter 6. Deep well disposal of the reject brine stream is the most economical approach, if the two conditions discussed previously are achieved. Solar evaporation is the second least cost alternative, assuming that 1,000 acres of land within a reasonable distance from the Village is available for purchase. If neither of the above alternatives are possible, multi-effect evaporators would be required.

6.3 Allocation of Treatment Costs

The capital and operating expenditures for any TDS removal system must be allocated among the industrial firms. Figure 6-2 summarizes the apparent existing loadings (March 1976) of the five firms. The total loading of 1,089,900 pounds/day after neutralization is nearly double the loading utilized in the conceptual design presented by Sauget (542,000 pounds/day after neutralization, see Section 6.2). The conceptual design was assumed to represent the final loading on the plant after completion of all flow reduction programs; however, the relative loadings from Figure 6-2 were utilized for allocation of the costs.

According to the TDS contributions described in Figure 6-2, Midwest Rubber's TDS loading is negligible, less than 0.1% and was assumed exempt from any allocation. Although Cerro Copper's discharge is below 3,500 mg/ℓ TDS, their flow is the second largest. An exemption for Cerro could be considered since they are below 3,500 mg/ℓ; however, their 11,000 pounds/day of TDS is significant. For this analysis, Cerro was included in

Table 6-1

SUMMARY OF CAPITAL AND ANNUAL COSTS* FOR REVERSE OSMOSIS PLANT WITH BRINE DISPOSAL AT SAUGET

	Alternative		
	R.O. with Deep Well Disposal	R.O. with Multi-Effect Evaporator	R.O. with Solar Evaporation Ponds
Total Capital Investment	7,720,000	10,300,000	12,300,000
Annual Costs			
Annualized Capital	900,000	1,200,000	1,380,000
Electrical	260,000	240,000	250,000
Fuel (Coal)	30,000	880,000	30,000
Operating Labor	120,000	210,000	120,000
Maintenance	230,000	300,000	300,000
Chemicals	200,000	200,000	200,000
Sludge Disposal	--	1,000,000	1,250,000
Total Annual Cost	$1,740,000	$ 4,030,000	$ 3,530,000

* 1975 dollars

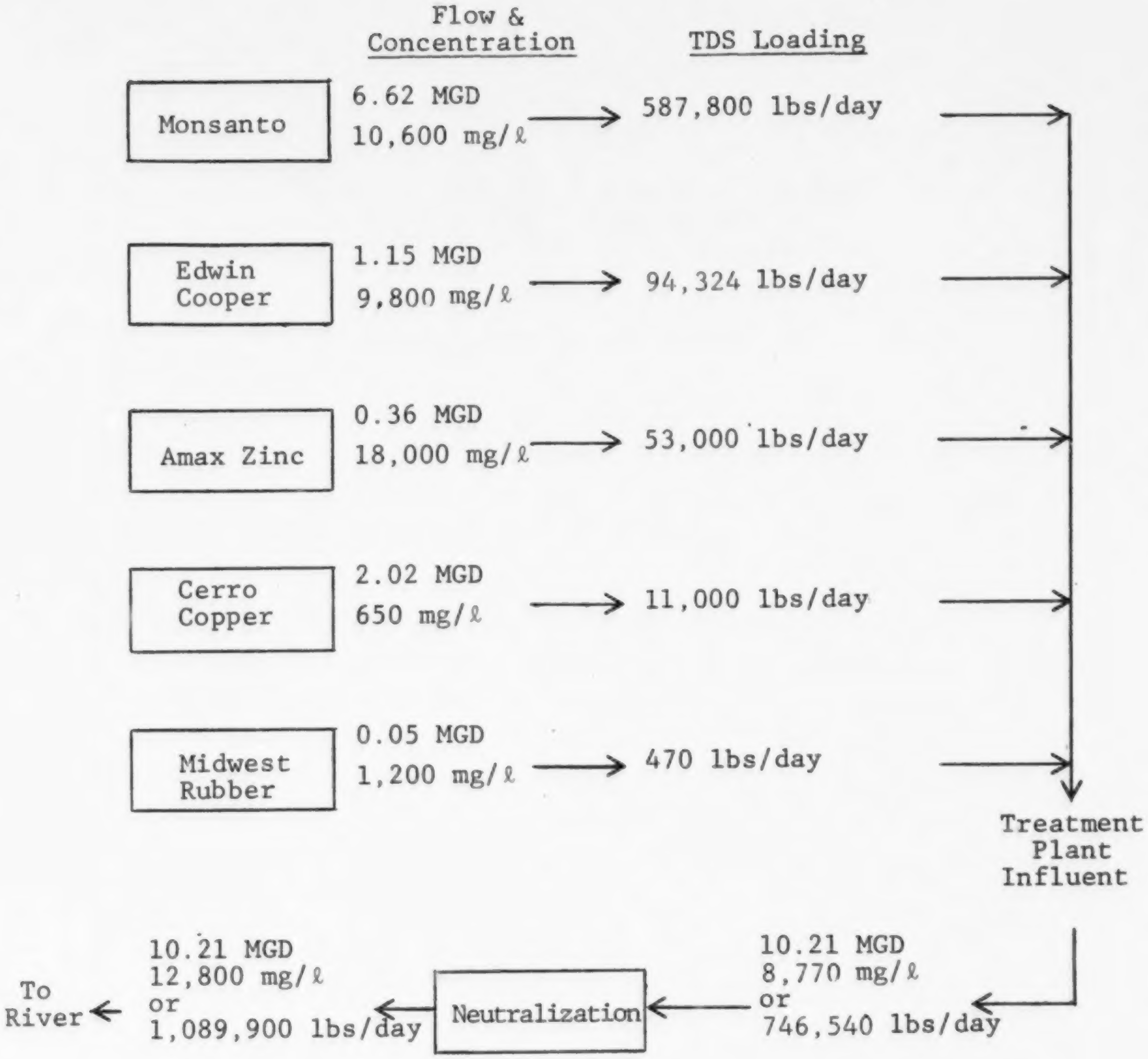

Flow & Concentration
TDS Loading
Monsanto
6.62 MGD
10,600 mg/ℓ
587,800 lbs/day
Edwin Cooper
1.15 MGD
9,800 mg/ℓ
94,324 lbs/day
Amax Zinc
0.36 MGD
18,000 mg/ℓ
53,000 lbs/day
Cerro Copper
2.02 MGD
650 mg/ℓ
11,000 lbs/day
Midwest Rubber
0.05 MGD
1,200 mg/ℓ
470 lbs/day
Treatment Plant Influent
10.21 MGD
8,770 mg/ℓ
or
746,540 lbs/day
Neutralization
10.21 MGD
12,800 mg/ℓ
or
1,089,900 lbs/day
To River

Figure 6-2

1976 LOADINGS ON THE VILLAGE TREATMENT PLANT the allocation, which was based upon pounds per day TDS. The following cost allocation was assigned (based on the loadings in Figure 6-2).

Company	% of Total Loading, or % of Total Charges
Monsanto	78.7
Edwin Cooper	12.6
Amax Zinc	7.1
Cerro Copper	1.5
Midwest Rubber	0

Utilizing the above percentages, cost allocations for the three alternative treatment schemes were prepared and are shown in Table 6-2. These cost allocations will be used in the following sections to ascertain the economic impact of the existing TDS effluent standard will have on each of these industries.

6.4 Industry Economics

There are five distinct industrial dischargers to the Village of Sauget which can be impacted by increased capital and operating costs for the treatment plant. The summary statistics regarding employment and product output are contained in Table 6-3. If treatment of total dissolved solids is required, then the costs of control must be allocated among the dischargers. The effect of additional costs can only be considered on a discharger basis since the economic status of each firm is unique. The economic background of each industrial discharger, which is delineated in Table 6-3, will be discussed in the ensuing sections. This background is important in determining the anticipated price and employment responses to increased costs.

6.4.1 Monsanto Company, W. C. Krummerich Plant

The W. C. Krummerich Plant of Monsanto, located in Sauget, employs 1,300 people in its industrial chemicals operation. Over 40 types of chemicals are produced at Sauget, and the product mix is continually changing depending upon the entry of new products. The major product types are inorganic chemicals, such as caustic soda and chlorine, organic plasticizers,

Table 6-2

COST ALLOCATION BY INDUSTRY

Alternative 1 -- Reverse Osmosis with Deep Well Disposal

	Monsanto	Edwin Cooper	Amax Zinc	Cerro Copper	Total
Capital Invest., $	6,080,000	970,000	550,000	120,000	7,720,000
Annual Cost[1], $	1,370,000	220,000	120,000	30,000	1,740,000

Alternative 2 -- Reverse Osmosis with Multi-Effect Evaporator

	Monsanto	Edwin Cooper	Amax Zinc	Cerro Copper	Total
Capital Invest., $	8,110,000	1,300,000	730,000	150,000	10,300,000
Annual Cost[1], $	3,170,000	510,000	290,000	60,000	4,030,000

Alternative 3 -- Reverse Osmosis with Solar Evaporation Ponds

	Monsanto	Edwin Cooper	Amax Zinc	Cerro Copper	Total
Capital Invest., $	9,700,000	1,550,000	870,000	180,000	12,300,000
Annual Cost[1], $	2,790,000	440,000	250,000	50,000	3,530,000

---

[1] Includes Annualized Capital Investment

Table 6-3

ECONOMIC SUMMARY OF VILLAGE OF SAUGET DISCHARGERS

Firm	SIC	Number of Employees	Type of Product	Annual Output
Amax Zinc	3333	450	Zinc slabs, cadmium, and acid	83,820 short tons[1]
Cerro Copper	3051, 3022	600	Electrolytic copper and copper tubing	42,000 tons copper cathode 55,000 tons copper tubing[2]
Edwin Cooper	2818	140	Organic chemicals	--
Midwest Rubber	3031	250	Reclaimed rubber	87,000,000 lb/year[3]
Monsanto	281, 2818	1,300	Inorganic and organic chemicals	1,200,000,000 lb/year[4]

[1] Production figure obtained from Hallowell, et al., Water Pollution Control in the Primary Nonferrous-Metals Industry, U.S. EPA, September 1973.

[2] Annual Report, Cerro Corporation, 1974 -- plant capacity.

[3] Production obtained from U.S. EPA, Economic Analysis of Effluent Guidelines for the Rubber Processing Industry, 1975.

[4] Data supplied by Monsanto Company.

flame retardants, and gasoline additives. The Krummerich Plant competes with ten other industrial chemicals plants within Monsanto for new processes and capital expenditure money. Thus, the effect of increased costs due to pollution control for this plant should be determined on a plant basis.

Therefore, the economic characteristics of the chemical industry in general and Monsanto in particular are offered as a background to the impact analysis. The demand/supply characteristics of the industry are delineated and the financial position of Monsanto Company is described according to available data in annual reports and technical marketing literature.

6.4.1.1 Industry Profile

The industrial chemicals group embraces a wide variety of products from fertilizers to synthetic fibers. Because of the growth and varied product type of this industry, there are a large number of firms engaged in these activities. There are approximately 86 firms that each have worldwide sales of industrial chemicals in excess of 100 million dollars per year.[13] The top eight firms, which includes Monsanto, represent over 25% of the total sales of the industry. Thus, although there are many firms, it is also a somewhat concentrated industry.

Monsanto Company is involved in five major activities as reflected by the divisions within the company. In Table 6-4 the sales and operating income attributed to each division are presented. Industrial Chemicals is an important division which contributes 27% of the sales and 31% of the operating income.

6.4.1.2 Industry Growth

The chemical industry has been a dynamic and growing sector compared to the overall growth in the economy. Since 1954, the output of industrial chemicals has increased at a rate of 9.3% per year compared to 4.5% for all manufactured goods.[13] This is attributed to the large number of new products

Table 6-4

PRODUCT DIVISIONS OF MONSANTO

Division	1974 Net Sales (million dollars)	1974 Operating Income (million dollars)	% Total Operating Income
Agricultural Products	410.7	202.5	36.8
Commercial Products	497.8	4.8	0.9
Industrial Chemicals	947.1	171.5	31.2
Polymers & Petrochemicals	854.6	136.4	24.8
Textiles	787.7	35.2	6.3
Total	3,497.9	550.2	100.0

Source: Moody's Industrial, 1975.

developed and entry into the chemical market. Technological innovations in products have helped to maintain the high growth rate of this industry. The total number of establishments in SIC 2818 sector has increased from 334 in 1958 to 488 by 1967 and 514 in 1972, as shown in Table 6-5, and the value of shipments has also increased as shown in Table 6-6. The larger plant sizes, as expected, represent the largest market share in value of shipments. Thus, the competition in a growing, dynamic market is very intense. These characteristics are important in determining the possible responses of Monsanto to increased costs. It should be noted in Table 6-5 that the Sauget establishment with 1,300 employees represents one of the largest plant sizes and has been a growing category since 1967.

6.4.1.3 Profitability and Price

Because of the increase in competition and supplies of chemicals, the prices of these materials have declined from 1948 to 1973. In Figure 6-3, the wholesale price index for chemicals is depicted, which contrasts markedly with the price trend for all industrial commodities.

With declines, the profitability of these firms could only be maintained by lowering production costs. Increases in productivity and processing made it possible for the industrial chemicals industry to obtain above average profits until 1966. Figure 6-4 shows the average profit trend in this industry from 1948 to 1973. From 1966 to 1972, increasing costs and competition resulted in profits below the average return of the manufacturing industry. Because of the dramatic increase in costs of raw materials since 1973, chemical prices have finally risen. Above average profits have accompanied the higher prices for this industry.

In Table 6-7, Monsanto's 1968 through 1974 net income as a percent of sales and as percent of net worth is recorded. Monsanto's profit trends shown in Table 6-7 have closely followed that of the industry's, presented earlier in Figure 6-4.

Table 6-5

GROWTH OF INDUSTRIAL ORGANIC CHEMICALS*

Establishment Size by Number of Employees	1967 Number of Establishments	1972 Number of Establishments	Percent Change
1 - 4	125	119	- 4.8
5 - 9	49	50	+ 2.0
10 - 19	46	50	+ 8.7
20 - 49	69	82	+ 18.8
50 - 99	50	56	+ 12.0
100 - 249	70	77	+ 10.0
250 - 499	38	31	- 18.4
500 - 999	21	24	+ 14.3
1,000 - 2,499	13	19	+ 46.2
2,500 +	7	6	- 14.3
Total	488	514	+ 5.3

*SIC 2818 in 1967 and SIC 2869 in 1972.

Source: U.S. Census of Manufacturers; 1967, 1972.

Table 6-6

SIC 2869

VALUE OF SHIPMENTS BY ESTABLISHMENT SIZE

Establishment Size by Number of Employees	1972 Value of Shipments (million dollars)	Market Share by Value of Shipments (%)
1 - 4	13.7	0.1
5 - 9	28.9	0.3
10 - 19	54.6	0.6
20 - 49	246.3	2.7
50 - 99	457.7	5.0
100 - 249	1,429.4	15.5
250 - 499	1,139.7	12.4
500 - 999	1,542.5	16.8
1,000 - 2,499	2,580.3	28.1
2,500 +	1,686.1	18.4

Source: 1972 U.S. Census of Manufacturers.

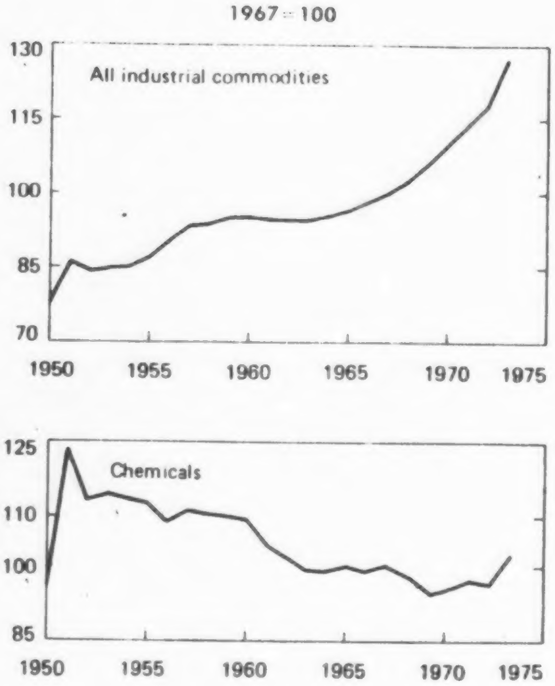
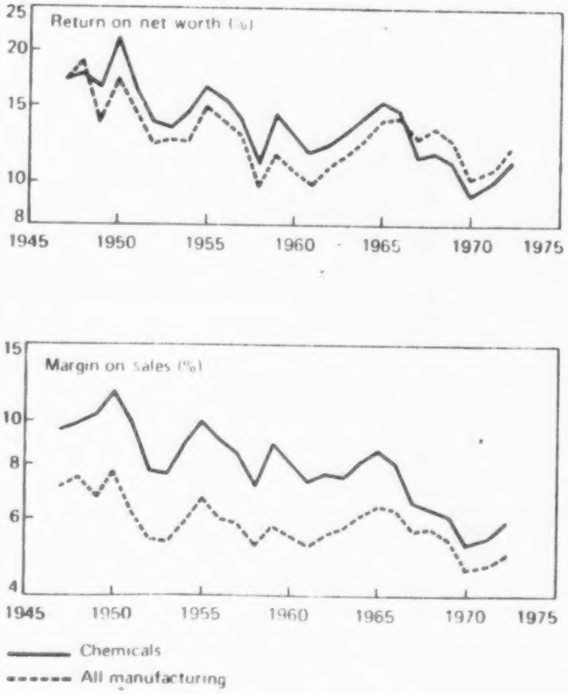


Figure 6-3

WHOLESALE PRICES INDEXES OF CHEMICALS AND ALL INDUSTRIAL COMMODITIES 1950-1973



Source: *First National City Bank Monthly Economic Letter.*

Figure 6-4

PROFITS IN CHEMICALS AND ALL MANUFACTURING 1947-1972

Source: The Kline Guide to the Chemical Industry, 1974

Table 6-7

MONSANTO's NET INCOME AND NET WORTH RECORD

Year	Net Income as % of Sales	Percent of Net Income to Net Worth
1968	6.07	15.92
1969	5.64	9.08
1970	3.95	6.45
1971	4.49	7.65
1972	5.48	9.43
1973	9.00	16.06
1974	9.24	18.42

Source: Moody's Industrial Manual, 1975.

6.4.1.4 Product Specialization

Each chemical company offers a wide variety of products and individual plants may be geared for production of a specific material or, like the Krummerich Plant, a multitude of products. Because of the extensive research in the chemical field, new products continually enter the market.

Monsanto's Sauget plant has the following major product lines:

- phosphate esters
- sodium hydroxide
- sulfuric acid
- rubber chemicals
- chlorine
- chlorophenols
- monochlorobenzene
- muriatic acid
- nitro anilines
- orthonitrophenol
- phosphorus pentasulfide
- para nitro chlorobenzene
- sodium sulfite
- chlorosulfonic acid
- dry bleach
- potassium hydroxide

With the exception of a few specialized chemicals, the number of firms which produce similar or the same product varies from 3 to as many as 25. Thus, there is price competition from other firms who can offer the same product. The chemicals produced at the Monsanto Krummerich Plant must be competitively priced to maintain its customers.

6.4.1.5 Capital Expenditures

The industrial chemicals industry is one of the most capital demanding industries. Because of the introduction of new products and obsolescence of old ones, a high rate of expenditures has been required. In 1971, approximately 7.4% of the sales income was expended on capital improvements, which was the highest percentage of any industry.[13] Figure 6-5 depicts the trend in capital expenditure since 1958 for the chemical industry in general. These dollars can be categorized

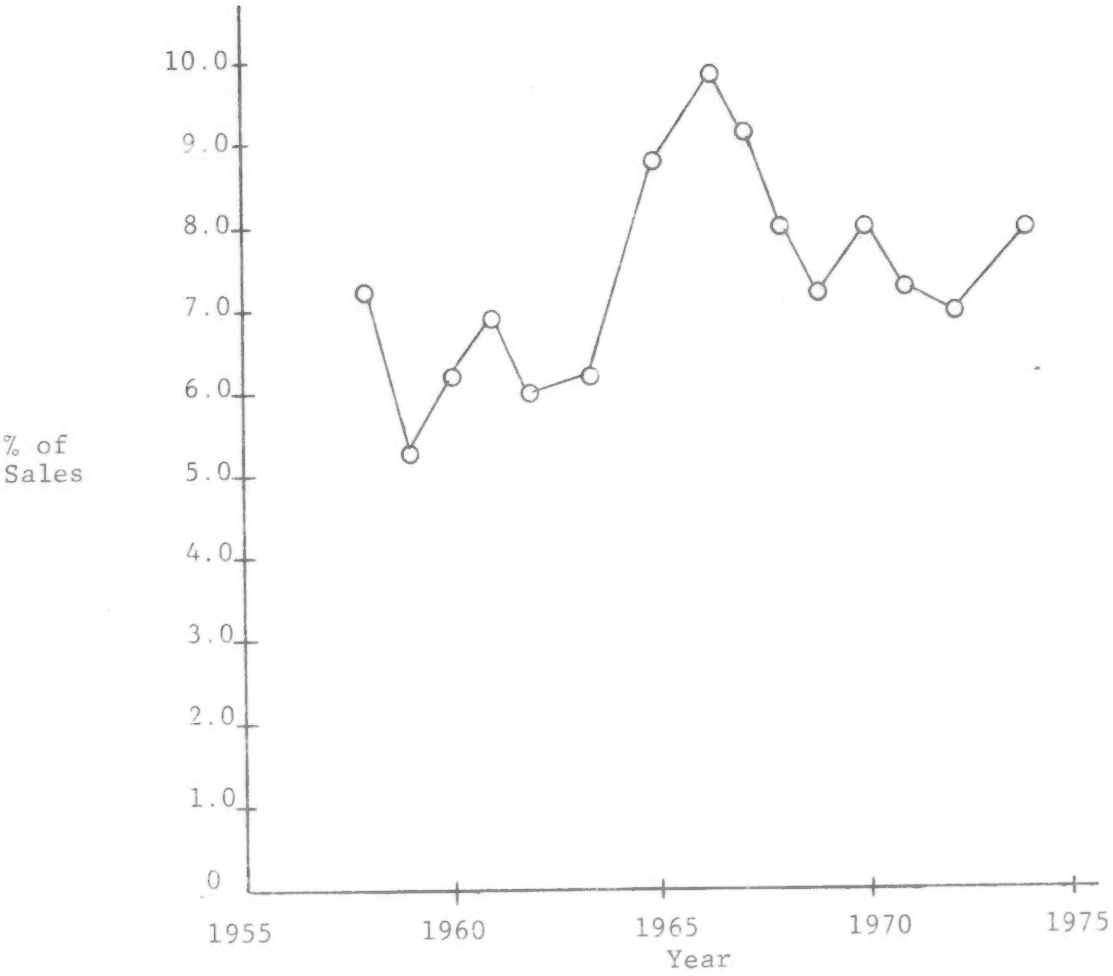


Figure 6-5

AVERAGE CAPITAL EXPENDITURE AS % OF SALES FOR INDUSTRIAL CHEMICALS INDUSTRY

Source: The Kline Guide to the Chemical Industry, 1974 according to plant size utilizing data from the U.S. Census of Manufacturers. In Table 6-8, the 1967 and 1972 capital costs are summarized by plant size. The 1972 expenditures for a plant similar in size to the Krummerich Plant were $10,300,000 or 8% of the value of shipments. This includes, of course, plant expansions, new plants, and process equipment. Monsanto's own rate of capital expenditure in 1972 was 7.6% of total sales.

6.4.1.6 Market Demand/Supply

Monsanto is in a very competitive, growing industry in which price competition has been very important. The capital expenditures for new processes have been high in the past and will continue as long as the chemical industry grows. Without product differentiation, price is one of the most important factors in demand. Any increase in price which is singular to the Sauget plant will affect their competitive position; not only in the market plant, but also within the competitive structure of Monsanto's facilities.

6.4.2 Edwin Cooper Company

Edwin Cooper Company is a privately held firm located in the Sauget, Illinois, area. The industrial product lines associated with this plant are organic chemicals categorized under Standard Industrial Classification (SIC) No. 2818. Thus, the comments pertaining to the type of market in which Monsanto competes can be considered applicable also to Edwin Cooper. As a plant with 140 employees, the range of products at Edwin Cooper is much smaller than that of Monsanto.

Expansion of the plant is planned in the next five years with the resulting closure of some plant facilities. To provide an indication of the ongoing process of renovation and expansion, Table 6-9 summarizes the age and status of each plant unit. Annual capital expenses are estimated by Edwin Cooper at two million dollars for this plant.

As an organic chemical manufacturing establishment with 140 employees, Edwin Cooper would probably produce a value of

Table 6-8
SIC 2818
CAPITAL EXPENDITURES BY ESTABLISHMENT SIZE

Establishment Size by Number of Employees	1967 Capital Expenditure per Establishment, (million dollars)	1972 Capital Expenditure per Establishment (million dollars)
1 - 4	0.6	-
5 - 9	0.02	-
10 - 19	0.03	0.07
20 - 49	0.2	0.3
50 - 99	0.6	0.2
100 - 249	1.2	0.8
250 - 499	4.2	2.1
500 - 999	7.7	4.4
1,000 - 2,499	9.7	10.3
2,500 +	19.1	24.1

Source: U.S. Census of Manufactures, 1967, 1972.

Values are obtained by dividing total capital expenditures per class by the number of establishments in that class.

Table 6-9

SUMMARY OF FACILITIES AT THE EDWIN COOPER PLANT

Unit	Age of Unit (years)	Expansion Status
1	10 - 30	no recent expansion
2	8	no recent expansion
3	19	no recent expansion
4	3 - 10	1973 last expansion
5	3 - 16	1973 last expansion
6	11	1974 last expansion
7	New	built in 1976
8	11 - 30	no recent expansion

Source: Personal communication from Edwin Cooper, April 8, 1976.

shipments of approximately $18,500,000, based on the 1972 Census of Manufacturers value of shipments for SIC 2818.* Trends in prices and profitability for organic chemicals were discussed for Monsanto and are also applicable for Edwin Cooper.

6.4.3 Midwest Rubber Reclaiming Company

The Midwest Rubber Reclaiming Company, located in Sauget, is a wholly-owned subsidiary of the B. F. Goodrich Company. Approximately 250 employees are utilized in the production of reclaimed natural and synthetic rubber from scrap materials and the mixing of rubber compounds to customer specifications. The reclaimed rubber is sold directly to rubber goods manufacturers as a raw material input. The economic characteristics of the reclaimed rubber industry are offered as a background to the discussion of potential adverse effects as a result of TDS regulation.

6.4.3.1 Industry Profile

Only eight plants representing eight different companies are in the business of manufacturing reclaimed rubber. Midwest has the largest capacity of any of these plants in the industry. In 1971, only 1,200 employees were associated with the entire rubber reclaiming industry.[7] The major producers of reclaimed rubber are Midwest, Uniroyal, Goodyear, and Firestone.

The primary markets served by the reclaiming industry are the tires and auto industries. Approximately 77% of all reclaimed rubber is utilized by these two customer segments. In Figure 6-6, the material inputs and inputs of the reclaim rubber industry are related to the customer markets.

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* In 1972 Census of Manufactures, SIC number changed from 2818 to 2869.

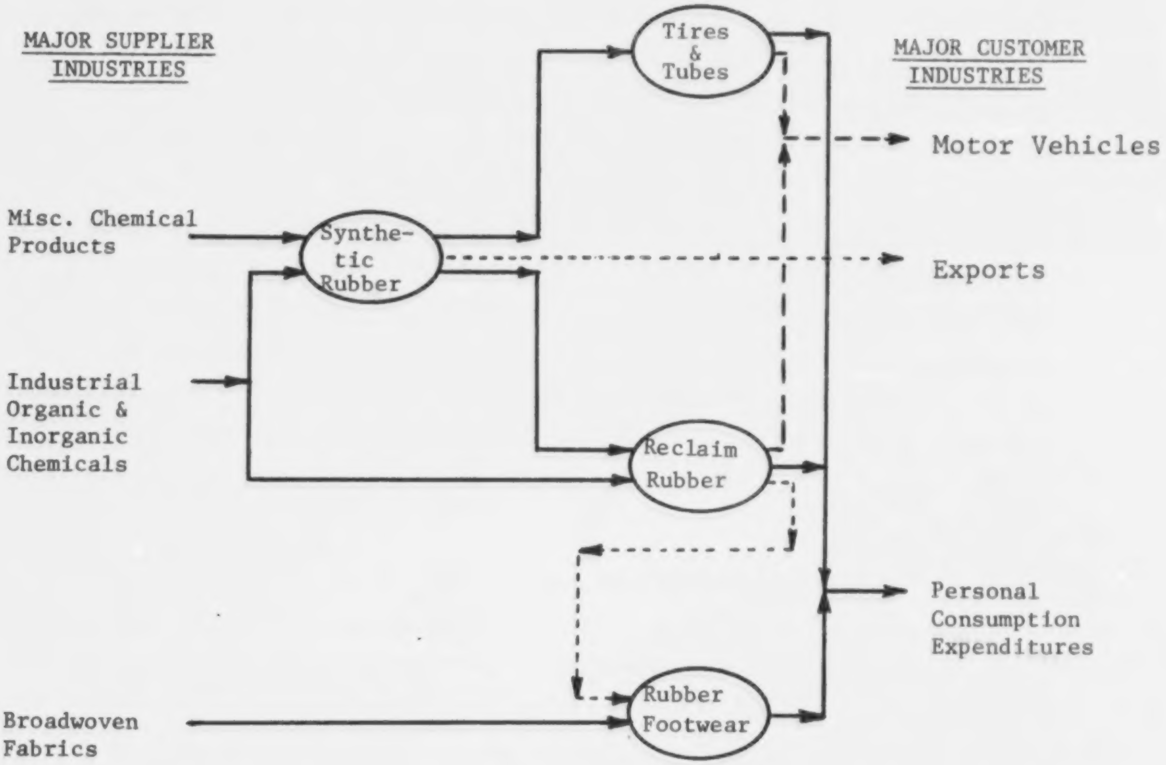
MAJOR SUPPLIER INDUSTRIES
MAJOR CUSTOMER INDUSTRIES
Tires & Tubes
Motor Vehicles
Misc. Chemical Products
Synthetic Rubber
Exports
Industrial Organic & Inorganic Chemicals
Reclaim Rubber
Personal Consumption Expenditures
Broadwoven Fabrics
Rubber Footwear

Figure 6-6: CUSTOMERS AND SUPPLIERS OF THE RUBBER INDUSTRY

Source: U.S. Dept. of Commerce, U.S. Industrial Outlook, 1974

6.4.3.2 Industry Growth

Because of low prices and ready availability of new rubber and the limited customer market, the reclaimed rubber industry has been declining steadily. Production has dropped from 565 million pounds in 1968 to 430 million pounds in 1973.[7] Midwest Rubber, which once operated three plants, has only the Sauget facility in production today. Value of shipments have declined from $49.2 million in 1960 to $41.9 million in 1973, which is a real decrease of 41%.* Accompanying this production decline is a loss in industry workers from 2,200 in 1958 to 1,200 in 1971.

Because of the oil crisis, demand has recently increased for reclaim rubber. Also, shortages of synthetic elastomers and compounding ingredients will increase the prices of synthetic and natural rubber, thus improving the competitive position of reclaim rubber. The future growth of this industry depends not only on the demand for new tires but also the price competition from two substitutes, synthetic and natural rubber.

6.4.3.3 Profitability and Price

In order to compete in the market place with oil extended virgin rubber, the product price of reclaimed rubber has remained low. With rising costs for scrap tire collection and labor, the reclaim industry is in a profit squeeze and many plants operate at a loss or at a low profit margin.[7]

6.4.3.4 Product Specialization

Midwest manufactures three product lines: reclaimed rubber, reprocessed synthetic rubber, and mixed rubber compounds. In 1974, mixed rubber compounds accounted for 55% of the firm's net sales and reclaimed rubber 35%, as shown below.[14]

---

* Based on a 15% decline in value of shipments multiplied by the wholesale price index.

Product Line	1974 Net Sales
Reclaimed Rubber	$ 8,352,000
Mixed Rubber Compounds	13,375,000
Reprocessed Synthetic Rubber	2,427,000

6.4.3.5 Capital Expenditures

Typically, capital expenditures have been low in the reclaim rubber industry. In 1971, only $700,000 was spent by the entire eight firms in the industry.

The capital expenditures associated with Midwest Rubber as a company (including its two subsidiaries) have varied substantially each year. The 1971 through 1974 capital investments listed below range from $387,000 to a high of $1,600,000.[14]

Year	Capital Expenditure
1971	$ 387,000
1972	936,000
1973	1,600,000
1974	649,000

6.4.4 Cerro Copper Products

The Cerro Copper plant in Sauget employs 600 people in its copper fabrication operations. Electrolytic copper is produced as well as copper mill products, such as tubing. A capacity of 42,000 tons of copper cathodes and 55,500 tons of copper tubing are available at the Sauget plant. The copper tubing is sold primarily to plumbing, air conditioning, and refrigeration wholesalers while the electrolytic copper is sold to a variety of copper fabricators. Cerro Copper Products is the largest of four divisions within the Cerro Corporation, and there are eight plants involved in the manufacture of copper and brass products within Cerro.

6.4.4.1 Industry Profile

There are 25 primary domestic copper tube companies in the United States. Many of these competitors are fully integrated with captive sources of copper. Cerro, however, is dependent on non-captive sources of supply.

To illustrate the marketing sequence of copper and its products, Figure 6-7 presents the chronological manufacturing process. Although many firms process copper from the mine to final fabrication, Cerro is basically employed in copper rolling and drawing with the exception of its electrolytic process. Customers engaged in construction activity are an important factor in overall demand.

In Table 6-10, the number of establishments and market share by value of shipments are presented according to size classes. In 1972, there were only 22 establishments with more than 500 employees but they accounted for approximately 50% of the industry shipments.

6.4.4.2 Industry Growth

The copper industry has been plagued by capacity substantially in excess of demand despite a long-term growth pattern of 4.3% per year.[15] There are 16 refineries and 17 smelters in the United States involved in the primary development of copper. Cerro, aside from its electrolytic operation, is engaged in the rolling and drawing of copper (SIC 335). Overall employment from 1958 to 1972 has decreased by 6.4% for this segment of the copper industry, although the number of establishments has increased from 105 to 148. Because the customer demand for these products (tubing) is related to industrial and residential construction, the growth in this sector is affected by construction activity.

6.4.4.3 Profitability and Price

Copper prices, which had steadied in the world market in 1971-1972, have recently been rising erratically. Due to record demand, prices peaked in mid-1974 for refined copper.

The margin between raw copper prices and refined copper typically have been small. Thus, electrolytic operation, such as the one at Cerro, operates on a very restrictive

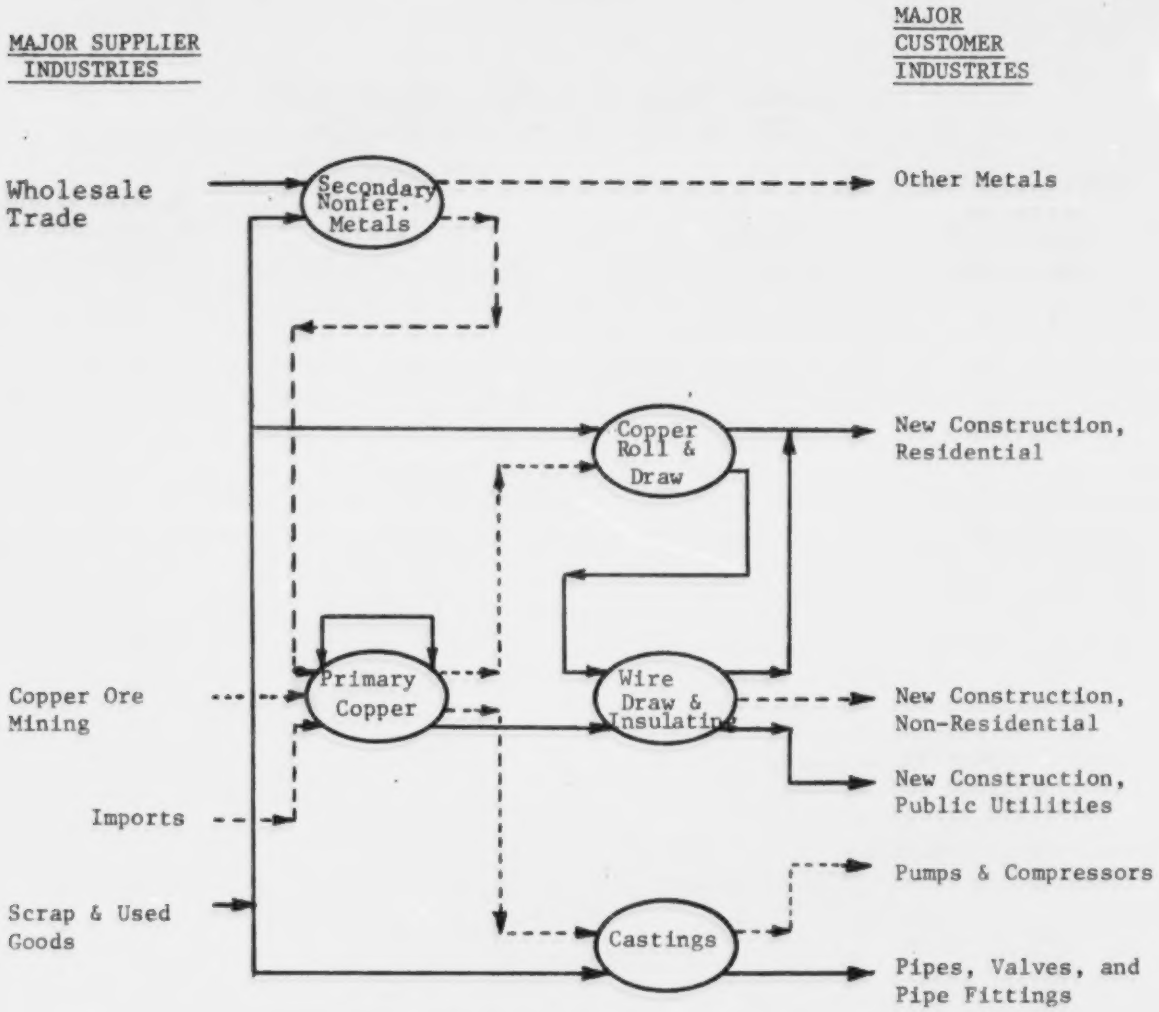
MAJOR SUPPLIER INDUSTRIES
MAJOR CUSTOMER INDUSTRIES
Wholesale Trade
Secondary Nonfer. Metals
Other Metals
Copper Roll & Draw
New Construction, Residential
Primary Copper
Wire Draw & Insulating
Copper Ore Mining
New Construction, Non-Residential
New Construction, Public Utilities
Imports
Pumps & Compressors
Scrap & Used Goods
Castings
Pipes, Valves, and Pipe Fittings

Figure 6-7: CUSTOMERS AND SUPPLIERS OF THE COPPER INDUSTRY

Source: U.S. Dept. of Commerce, U.S. Industrial Outlook, 1974.

Table 6-10

SIC 3351

MARKET SHARE BY ESTABLISHMENT SIZE FOR COPPER ROLLING AND DRAWING

Establishment Size by Number of Employees	1972 Number of Establishments	1972 Value of Shipments (million dollars)	Market Share as Percent of Shipments
1 - 4	17	10.7	0.3
5 - 9	4	0.7	<.1
10 - 19	11	13.2	0.4
20 - 49	19	107.1	3.5
50 - 99	19	210.7	6.8
100 - 249	32	531.1	17.2
250 - 499	24	628.3	20.3
500 - 999	13	726.2	23.4
1,000 - 2,499	8	868.7	28.1
2,500 +	1		
TOTAL	148	3096.6	100

Source: U.S. Census of Manufactures, 1972 cost basis. Increased production costs for an individual producer certainly affect his economic position.

The historic corporate profits of Cerro are summarized in Table 6-11. These profits, as a percent of sales, are below the average of all manufacturing companies.

6.4.4.4. Capital Expenditures

The capital expenditures in the copper rolling and drawing industry (SIC 3351) averaged in 1972 only 2.1% of the value of shipments. The actual expenditures per establishment size are estimated in Table 6-12 from U.S. Census of Manufacturers.

The Cerro plant of 600 employees would thus have an average capital expenditure in 1972 of $530,000 , based on the data presented in the Census of Manufacturers.

6.4.5 Amax Zinc Company

Amax Zinc Company in Sauget, Illinois, is one of seven plants in the United States operating primary slab zinc and custom smelting facilities. The economic characteristics of the zinc industry in general and Amax in particular are offered as a background to the impact analysis. The demand/supply characteristics of the industry are delineated, and the financial position of Amax is described according to information available in annual reports and technical articles.

6.4.5.1 Industry Profile

The primary zinc industry (SIC 3333) refines zinc by a variety of processes, including the electrolytic one of Amax. In 1972, there were 15 establishments operating in this SIC category. The 1972 United States plant capacity was 755,000 short tons, and the Sauget plant represents approximately 10% of the nation's capacity.

In Table 6-13, the distribution and value of shipments of plants according to size is presented. Amax, with approximately 450 employees, falls into the aggregated class due to the small number (2) of plants in this size group. There are

Table 6-11

SUMMARY OF CERRO CORPORATION's EARNINGS

Year	Earnings as a Percent of Sales	Percent Net Income to Net Worth
1969	7.28	-
1970	1.40	-
1971	0.67	-
1972	2.05	-
1973	2.33	14.21
1974	2.03	4.51

Source: Moody's Industrial Manual, 1975.

Table 6-12

CAPITAL EXPENDITURES IN SIC 3351

Establishment Size by Number of Employees	1972 Average Capital Expenditures per Firm ($)
1 - 4	17,650
5 - 9	-
10 - 19	9,090
20 - 49	68,420
50 - 99	121,050
100 - 249	218,750
250 - 499	858,330
500 - 999	530,770
1,000 - 2,499	3,337,550
2,500 +	

Table 6-13

SIC 3333

NUMBER AND VALUE OF SHIPMENTS BY ESTABLISHMENT SIZE

Establishment Size by Number of Employees	Number of Establishments	1972 Value of Shipments (million dollars)
20 - 49	4	90.3
50 - 99	3	*
250 - 499	2	*
500 - 999	5	286.1
1,000 - 2,499	1	*

*The class value appears in the aggregated underscored figure.

six establishments with over 500 employees or, in other words, 40% of the establishments are larger than Amax.

6.4.5.2 Industry Growth*[16]

The world demand for zinc has grown steadily at a rate of 3.5 to 4.0% per year; however, United States Consumption has fluctuated. The reason for variations in demand is that 39% of the zinc produced is utilized in die castings for the automotive industry. Other uses of zinc are as follows:

- galvanizing - 40%
- brass - 11%
- rolled zinc - 3%
- zinc oxide - 4%
- other - 3%

The number of establishments in SIC 3333 has decreased from 1958 to 1972 from 20 to 15, although actual output has risen from 842,990 to 930,100 short tons per year. Thus, an overall growth is experienced even though there are fluctuations associated with customer demand declines.

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* Description based on U.S. EPA, "Economic Impact of Proposed Water Pollution Controls on the Nonferrous Metals Industry", March 1975.

6.4.5.3 Profitability and Price

Typically, the actual costs of smelting and refining are small compared to the price of zinc. These operations are operated at a fixed and relatively low profit margin because these activities are "service operations" of conversion.[16] In 1972, the operating margin was $0.08 to $0.10 per pound of zinc for the processor and refiner. Any significant costs would be reflected in the mine price of zinc and passed on rather than absorbed. There has been rapid increase in zinc prices since 1970 as with other nonferrous materials.

The 1972 profitability is given in the Almanac of Business and Industrial Financial Ratios for nonferrous processors as shown below.

Asset Size	Net Income as % of Net Worth
$10-25,000,000	6.7
$25-50,000,000	4.2
$50-100,000,000	4.0

6.4.5.4 Capital Expenditures

Because of the small number of establishments in SIC 3333, the capital expenditures are aggregated for three establishment size classes. In 1972, nine million dollars was spent by 10 plants in three size classes. This is an average of $900,000 per plant, which may or may not be representative of individual expenses. Amax has spent approximately $3,700,000 on flow reduction measures within the Sauget plant.

6.5 Anticipated Economic Responses to TDS Regulation

The response of each industrial discharger in Sauget to additional imposed costs for TDS is based on the economic condition of the plant and the magnitude of the treatment cost burden. In each case, a microeconomic decision regarding price increases or decreases in production is related to the plant's finances. There is uncertainty with regard to the actual decision, and thus, only a range of probable reactions is appropriate for such an evaluation. To develop this possible range, the following three scenarios were considered for each discharger:

a) Pay costs of treatment for TDS

b) Close production facilities associated with TDS contributions

c) Combination of "a" and "b" responses

In-plant treatment was not considered an alternative since Monsanto estimated that in-plant treatment would cost more than treatment at the Village treatment plant.

The three scenarios described provided a range of anticipated responses, and according to the costs incurred, each plant will adjust output, employment, prices, and plans for expansion. For each of the five dischargers, a description of the range of responses is presented in this Section. This range represents the attitudes of the plants surveyed and an evaluation of their economic condition.

Table 6-14 presents a summary of the economic statistics utilized in this Section for calculating price, output, and employment changes. In Section 6.3, these background statistics were developed with regard to the industry market situation. The final results of this analysis are summarized in Table 6-15 for each of the five dischargers.

According to Table 6-15, enforcement of the existing TDS regulation will probably have a negligible effect on Cerro Copper and Midwest Rubber Reclaiming. Enforcement of the present standard would probably reduce Amax Zinc's expansion plans at Sauget, but would have a negligible effect on the current production facilities. Monsanto and Edwin Cooper would potentially lose between 0-600 and 0-52 employees, respectively, from enforcement of the existing regulation. In addition to a possible drop in production at Monsanto and Edwin Cooper from enforcement of the standard, future expansion plans would also be hampered. In fact, the major impact upon Sauget may be the loss of further expansion due to costs of TDS and enforcement of some upper limit. Present production capacities could be reduced in the long

Table 6-14

SUMMARY OF BACKGROUND ECONOMIC STATISTICS

Company	Net Sales or Value of Shipments ($)	Net Plant Equipment ($)	Annual Capital Expenditure ($)	Expenditures on Flow Reduction ($)
Midwest Rubber Reclaiming (1)	24,200,000	5,900,000	--	500,000
Monsanto Co. (2)	277,500,000	--	20,400,000	1,138,000
Amax Zinc (3)	55,000,000	--	1,320,000	3,700,000
Cerro Copper (4)	82,000,000	--	779,000	250,000
Edwin Cooper (5)	38,100,000	--	2,000,000	573,000
Total Village		40,924,028		

(1) Net Sales and Plant & Equipment values taken from 1972 Moody's while Flow Reduction Expenditure reported by company.

(2) Value of Shipments and Capital Expenditure taken from 1972 U.S. Census of Manufacturers average values for plants from 1,000-2,499 employees and updated with WPI for chemicals, Expenditures on Flow Reduction reported by Monsanto.

(3) Net Sales and Flow Reduction Expenses provided by Amax. Annual Capital Expenditures based on 1972 U.S. Census of Manufacturers average value for plants of 250-499 employees updated to 1975.

(4) Value of Shipments and Capital Expenditures based on 1972 U.S. Census of Manufacturers average values for plants of 500-999 employees updated to 1975 with WPI of non-ferrous metals. Flow Reduction costs provided by Cerro.

(5) Value of Shipments based on 1972 Census of Manufacturers average value for plants of 100-249 employees and updated to 1975. Capital Expenditure and Flow Reduction expenses reported by Edwin Cooper.

Table 6-15

SUMMARY OF ECONOMIC RESPONSES TO TDS REGULATION

Company	SIC	Possible Price Change (% Sales)	Possible Output Change (%)	Possible Number of Employees Change	Possible Expansion Losses
Monsanto	2818	0 - 1.0	0 - 46	0 - 600	1st year: 5% output + 35 jobs; no future expansion
Edwin Cooper	2818	0 - 1.3	0 - 37	0 - 52	25% additional output + 35 jobs
Amax Zinc	3333	0 - 0.5	0	0	10% output + 45 jobs
Cerro Copper	3351	0 - 0.07	0	0	no effect
Midwest Rubber Reclaiming	3031	0	0	0	no effect
Total				0 - 652	0-115 jobs plus future effects now unknown

Note: Possible expansion losses are based on short term (1 to 5 years) changes in plans.

run due to increased costs of operation. The impact on each discharger is discussed in detail in the following section. Only estimates of the probable range of responses is described due to the complexity of the microeconomic decisions performed by each plant.

6.5.1 Monsanto's Alternative Responses

As discussed in the TDS treatment cost Section, a total capital expenditure ranging between $7,720,000 and $12,300,000 and annual costs of $1,740,000 up to $4,030,000 are anticipated to achieve an effluent in compliance with the existing TDS discharge limitation. If these costs are allocated according to TDS loading contributions, then Monsanto's share of capital expenses could be between $6,080,000 up to $9,700,000 with annual operating costs of $1,370,000 to $2,790,000.

For each of the three possible scenarios which could be utilized by Monsanto to achieve compliance, the economic responses will be discussed. As a manufacturer in the organic and inorganic chemicals industry, Monsanto's plant must compete within the company for new processes and capital expenditures. Utilizing this market situation, the following three scenarios are considered.

6.5.1.1 Pay the TDS Treatment Costs

Three economic indicators -- product price, output, and employment -- describe the probable responses of Monsanto. By paying treatment costs for TDS control in Sauget, Monsanto has increased the production costs of its operation.

Capital costs of $6,080,000 to $9,700,000 represent approximately 30-50% of the annual capital expenditures for a plant of the typical size of the Krummerich facility. Any planned expansion would be severely curtailed by the limitation of funds, and the ability of this plant to effectively compete for new processes would be uncertain. Thus, the average annual growth in output of 5% could be lost for one year and, assuming a direct relationship between employees and output, approximately 35 potential jobs. It is difficult to predict the impact on long term expansion because of the new process innovation and inter-plant competition. However, the TDS regulation could eliminate the entry of any additional TDS generating processes.

Immediate changes in output and employment would probably be limited if product prices are increased to cover these expenses. Price rises for selected products that could best absorb the higher production costs would present one possible approach for covering costs. However, if the higher production costs are assigned to the product lines contributing to the TDS loading, price rises on these products would damage the Krummerich Plant's competitive position. On certain product lines, the higher production costs would have to be absorbed, thus a reduction in the profit margins would result.

For this analysis, any price increase was assumed to be passed on uniformly over all product lines. Based on the average value of shipments for a plant size similar to Monsanto's Krummerich Plant, the possible price increase could vary from 0% (all costs absorbed by company) to 1.0% (the highest possible costs passed on entirely in higher prices) to handle the TDS treatment costs.

The major impact of this alternative is the limitation of expansion and possible future loss of production activity due to TDS regulation and an eroded competitive position within Monsanto.

6.5.1.2 Reduction of TDS Loading

If Monsanto attempts to limit their TDS contributions by closing high-TDS processes, this could result in the most significant impact. To gain compliance, Monsanto would be required to reduce TDS loading from 588,000 to 161,000 pounds per day. Such a reduction might be possible through reduction of seven main process lines. However, the integration of Monsanto's facility could result in the closure of a large portion of the plant. The average number of employees per line, determined by using 35 lines and 1,300 employees, is approximately 35. Thus, the loss of employees would vary from 245 (closure of seven lines) up to as much as 600 if half the plant were shut down.

The change in output was determined according to the employee and product line closures. Thus, an approximate range for this alternative is 20% to 46% reduction in output. This, of course, would be a drastic response but it should be considered as a possible alternative.

6.5.1.3 Combination of TDS Reduction and Treatment

If a combination of in-plant TDS reduction and control technology is employed, this would indicate that the cost of transferring or removing a process line is less than the savings achieved in treatment costs. Also, if one process were replaced by a low TDS process, then the combination would occur. Responses to price, output, and employment changes would be similar to those discussed under Section 6.5.1.1 and such estimates would be considered applicable.

Table 6-16 summarizes the possible economic responses of Monsanto to each scenario discussed herein.

Table 6-16

SUMMARY OF MONSANTO's ECONOMIC RESPONSE

Scenario	Possible Change in Price	Possible Change in Output	Possible Change in Employment	Future Expansion
a	0 - 1.2%	0	0	Long term-uncertain. Short term loss of 5% output, 35 employees.
b	-	20 - 46%	245 - 600	Unlikely.
c	0 - 1.0%	0	0	Same as "a".

6.5.2 Edwin Cooper's Alternative Responses

As discussed in the TDS treatment cost section, the total capital expenditures of $7,720,000 to $12,300,000 with annual costs of $1,500,000 and $4,030,000, respectively, are anticipated to achieve an effluent in compliance with the existing TDS discharge limitation. If these costs are allocated according to TDS contributions, then Edwin Cooper's share of capital expenses is between $970,000 and $1,550,000 with annual operating costs from $220,000 to $510,000.

For each of the three possible scenarios which could be utilized by Edwin Cooper to achieve compliance, the economic responses will be discussed. As a member of the organic chemicals industry, the Edwin Cooper plant can consider the following three alternatives.

6.5.2.1 Pay the TDS Treatment Costs

Three economic indicators -- product price, output, and employment -- describe the probable response to Edwin Cooper. By paying the treatment costs for TDS control in Sauget, Edwin Cooper has increased the production costs of its operation. The capital cost of $970,000 up to $1,550,000 is approximately 48 to 78% of the plant's reported annual expenditure for increased production. Therefore, a delay in expansion would probably occur and could be curtailed, depending upon the plant's competitive position. The projected five year net output expansion of 25%, could thus be decreased to only 0% to 22% expansion. In terms of lost jobs, this potential loss could range from 2 to 35 employees at the plant if workers to output is considered a direct ratio.

Immediate changes in output and employment would probably be limited even with increased production costs. However, product prices could rise to cover these expenses. Utilizing the average value of shipments reported by the U.S. Census of Manufactures as an approximation of the total sales, the expected average price increase over all products could range from 0% to 1.3%, depending upon how much of the costs the firm absorbs. The actual price increase sustained would probably vary across product lines, depending upon the market position of the firm.

6.5.2.2 Reduction of TDS Loading

As an organic chemicals producer, the possibility of isolating and closing process lines which generate high levels of TDS appears to be small for Edwin Cooper. If closing process lines were considered, only three of the eight lines could be candidates for such an option. This observation is based on the age and expansion history of the eight lines. Only three have had no recent expansion and are older than 10 years. The number of marginal processes thus could vary from 0 to as many as 3. Thus, the effects of closing from 0 to 3 lines would represent the loss of 0 to 52 employees and from 0% to approximately 37% of the plant's output. These ranges represent estimates of the minimum and maximum responses which could be anticipated.

Expansion of the plant would also be limited under these conditions unless water usage were increased sufficiently to maintain an acceptable TDS concentration. Thus, the potential loss of expansion would be the same as discussed in Section 6.5.2.1.

6.5.2.3 Combination of TDS Reduction and Treatment

In the case of Edwin Cooper, the possibility of closing process lines to reduce TDS loading would only occur if the financial cost of closing a marginal line is less than the savings from reduced TDS treatment cost. Since Edwin Cooper is considering phasing out 10% of the old plant in their expansion plans, it appears that natural attrition is probably the only instance where Section 6.5.2.3 is feasible. Therefore, the price, output, and employment responses of Sections 6.5.2.1 and 6.5.2.2 appear to adequately cover the range of anticipated changes.

Table 6-17 summarizes the possible economic responses of Edwin Cooper to each senario discussed herein.

Table 6-17

SUMMARY OF EDWIN COOPER's ECONOMIC RESPONSES

Scenario	Possible Change in Price	Possible Change in Output	Possible Change in Employment	Future Expansion
a	0 - 1.3%	0	0	Jobs 2-35 % output 0-22%
b	0	0 - 37%	0 - 52	Unlikely.
c	-	-	-	-

6.5.3 Amax Zinc's Alternative Responses

As discussed in the TDS treatment cost section, total capital expenditures up to $12,300,000 and annual costs of $1,740,000 up to $4,030,000 are anticipated to achieve an effluent in compliance with the existing TDS discharge limitation. If these costs are allocated according to TDS loading contributions, then Amax Zinc's share of capital expenses could vary from $550,000 to $870,000 with annual operating costs between $120,000 and $290,000.

For each of the three possible scenarios which could be utilized by Amax Zinc to achieve compliance, the economic responses should be considered. As a member of the zinc ingot industry, the Amax Zinc plant can consider the following three alternatives.

6.5.3.1 Pay the TDS Treatment Costs

Three economic indicators -- product price, output, and employment describe the probable response to Amax Zinc to achieving compliance with the existing standard. By paying these treatment costs, Amax has increased the production costs of its operation and it must adjust accordingly.

The capital costs of $550,000 to $870,000 are between 40% and 70% of the plant's annual expenditure budget. Such costs would certainly delay any plant expansion or innovation. The 10% expansion planned by 1977 could be curtailed with the loss of 45 jobs. The profitability of the plant and availability of other facilities would affect the final decision on expansion.

Immediate changes in output and employment would probably be limited even with the additional costs. Product prices could rise to cover the additional treatment expense. Utilizing the sales information from Table 6-14, the product price increase could range from 0 to 0.5%, depending upon the ability of Amax to absorb costs. Present output and employment reductions are not assumed to be incurred if this option is utilized.

6.5.3.2 Reduction of TDS Loading

Amax Zinc has expended to date $3,700,000 on flow reduction measures. However, to reduce their TDS loading through in-plant control or output reduction appears impractical. In 1968, an extensive rennovation of the plant occurred and a 10% expansion is planned by 1977. TDS is generated through the process of zinc refining and only plant closure or output decrease could result in a TDS loading reduction. Output reduction is not a viable alternative because of the inherent TDS generation and monies expended to increase production.

6.5.3.3 Combination of TDS Reduction and Treatment

A combination of treatment and output reduction does not seem to be feasible because of the discussion in Section 6.5.3.2. The reduction in TDS costs achieved by output reduction could probably not offset the lost revenue of Amax. Thus, Section 6.5.3.3 is not a reasonable alternative. Table 6-18 summarizes the possible economic responses of Amax Zinc to each scenario discussed herein.

Table 6-18

SUMMARY OF AMAX ZINC's ECONOMIC RESPONSES

Scenario	Possible Change in Price	Possible Change in Output	Possible Change in Employment	Future Expansion
a	0 - 0.5%	0	0	Output = 10%, number of jobs = 45.

b -- not a probable response

c -- not a probable response

6.5.4 Cerro Copper's Alternative Responses

As discussed in the TDS treatment cost section, a total capital expenditure up to $12,300,000 and annual costs up to $4,030,000 are anticipated to achieve an effluent in compliance with the existing TDS discharge limitation. If these costs are allocated according to TDS loading contributions, then Cerro Copper's share of capital expenses ranges between $120,000 and $180,000 with annual operating costs between $30,000 and $60,000. Although there are three possible scenarios, only one is applicable to Cerro Copper. As a small contributor of TDS which are generated in the process, Cerro would pay these treatment costs rather than reduce production as long as production losses were greater than the savings in treatment costs. An increase in operating costs between $30,000 and $60,000 is relatively insignificant compared to the 1972 average value of shipments of $82,000,000, or 0.07% at most.

Incurring a $120,000 to $180,000 capital cost may retard future expansion plans which are unknown at this time. On an individual basis, Cerro considers their TDS in compliance and no problem to their operation. Thus, no immediate changes in output, price, or employment are anticipated.

Table 6-19 summarizes the possible economic responses of Cerro Copper to each scenario discussed herein.

Table 6-19

SUMMARY OF CERRO COPPER's ECONOMIC RESPONSES

Scenario	Possible Change in Price	Possible Change in Output	Possible Change in Employment	Future Expansion
a	0.07%	0	0	Uncertain effect.
b -- not a probable response				
c -- not a probable response				

6.5.5 Midwest Rubber's Alternative Responses

Midwest Rubber Reclaiming is a small source of TDS within the Village of Sauget. Producing only 0.06% of the TDS, the capital and operating costs which would be assessed to Midwest are almost negligible. Thus, no change in price, output, or employment is anticipated as a result of enforcing compliance with the existing TDS effluent limitation.

6.6 Regional Effects

The greatest impact on the Sauget area would be the result of Monsanto considering production line closures and the loss of future expansion plans. Expansion is retarded due to the capital costs of TDS loadings which may result in future violation of the TDS standard. The maximum potential loss of 600 present jobs and 115 future job opportunities is particularly significant to the East St. Louis region where unemployment is an important concern.

The change in goods, services, agricultural goods, employment, and prices on a statewide basis would be minimal because of the localized nature of the problem. This statewide effect is so small as to be considered a negligible impact of the rule change.

Chapter 7

COSTS AND BENEFITS OF REGULATION

7.1 Introduction

The measurement of the costs and benefits of an effluent regulation provides an indication of the accompanying resource allocation. In many instances, real-world constraints on data and quantification of benefits in dollar terms limit the practicality of applying a benefit-cost analysis. The benefit-cost analysis of a TDS regulation is not as straightforward as that for a toxic or hazardous material. Toxic substances which damage human health and aquatic life must be removed by dischargers to protect the environment. There really is no alternative for removal of these materials, which can so quickly damage the environment. Pollutants, such as TDS, primarily affect consumers who withdraw surface water for various purposes. Thus, it is possible to consider alternatives to effluent treatment, such as TDS removal by the public water supplies, for minimizing TDS quantities reaching the consumer.

A theoretical discussion of defining benefits is provided, because TDS regulation offers an opportunity to examine alternative ways of achieving the same objective. Through a discussion of all potential benefits associated with TDS regulation, some insight is provided on the value of the existing standard.

In Chapter 6, the costs of compliance with the existing TDS regulation were detailed for the Village of Sauget. An isolated view of the relative costs and benefits on the Mississippi River is presented in response to Sauget's proposed effluent amendment. Also included in this chapter is an overview of the TDS situation within the state and the anticipated benefits from regulation. This information is provided to depict another aspect of the economic impact on resources due to effluent regulation.

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7.2 Benefits of Regulation

In evaluation of effluent standards, the "results" of compliance have been considered achievement of a certain level of water quality. To obtain this level of water quality, costs are imposed on one group, while benefits are bestowed on another. The social welfare criterion, known as the Pareto criterion*, does not cover the public policy decisions related to pollution control since there is always a group which is made worse off by the control of pollution. Therefore, the general criterion utilized in this benefit-cost analysis is that of Kaldor-Hicks, which states that a change in resource allocation should be considered as an increase in welfare if the Pareto criterion is met or if those who gained from the reallocation could compensate those who were harmed leaving them as well off as before[17]. Translated into the application of benefit-cost analysis, the net effect of a project or policy should yield benefits in excess of costs. Maximization of this difference (willingness to pay less costs of providing it) is considered the "efficiency" objective. Two measurements of the efficiency objective are the willingness to pay and the evaluation of alternative costs[18].

Where there exists a demand for high-quality water, one can consider the alternative costs of obtaining this water. To illustrate the applicability of an alternative cost, the following example is offered. Shown in Figure 7-1 is a hypothesized water supply demand curve for water of a specific TDS concentration. Suppose that an output "D" is demanded, and this can be supplied at cost "E" through effluent TDS regulations on the dischargers. Now, if the same output "D" with

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* Pareto criterion of social welfare states that any change in social state is "desirable" if at least one person judges himself to be better off while no one else is made worse off by the change.

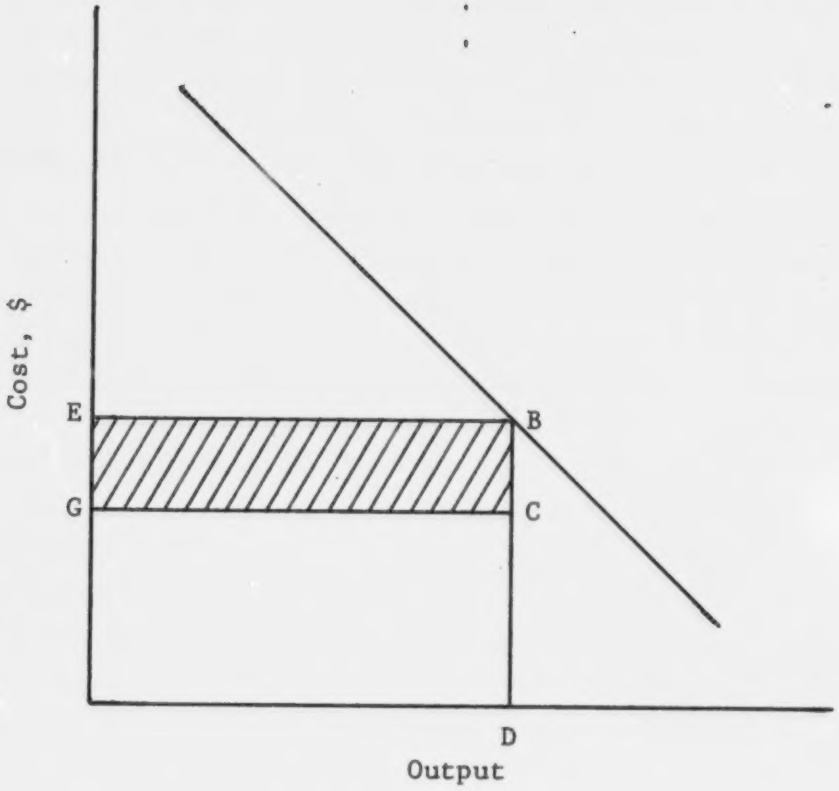


Figure 7-1

HYPOTHETICAL WATER SUPPLY DEMAND CURVE

the same water quality can be supplied at cost "G" by removing the TDS at the water supply intake stations, a net savings or benefit equal to the area "EGCB" in Figure 7-1 is realized.

It is important in the evaluation of specific regulations to also consider this type of alternative cost approach for accomplishing the same end. This provides a measure of the resource allocation efficiency of the regulatory solution over alternative measures for resolving the problem. In the instance of evaluating alternatives for a fixed output or objective, the use of the alternative cost approach should be considered as one of cost minimizing rather than net benefit maximizing.

The actual social benefits obtained from control of pollution can also be measured from demand curves, as shown in Figure 7-2. For water of a specific quality, the demand curve, "P_2D" can be developed. At a price of "P_1", "Q" gallons of water will be demanded by the users. The area "P_1P_2Q" represents the consumers' surplus, or the "willingness-to-pay". The total social cost or benefit is the total area under the demand curve, $P_2QQ'O$ in Figure 7-2, or:

$$P_1Q + \frac{(P_2 - P_1)Q}{2}$$

As water quality improves, the demand curve shown in Figure 7-2 shifts to the right. Water quality itself can be considered an economic good, with a demand curve for higher levels of quality at higher prices. A demand curve for water quality would be similar to that in Figure 7-2, if it could be estimated. To date, no one has been able to determine directly the price or value of improved water quality to the users who represent the demand for water.

The value of clean water is related to its various uses by consumer groups; and,by classifying the potential changes in welfare associated with a change in water quality, it may provide an indirect measure of the willingness to pay. Depending

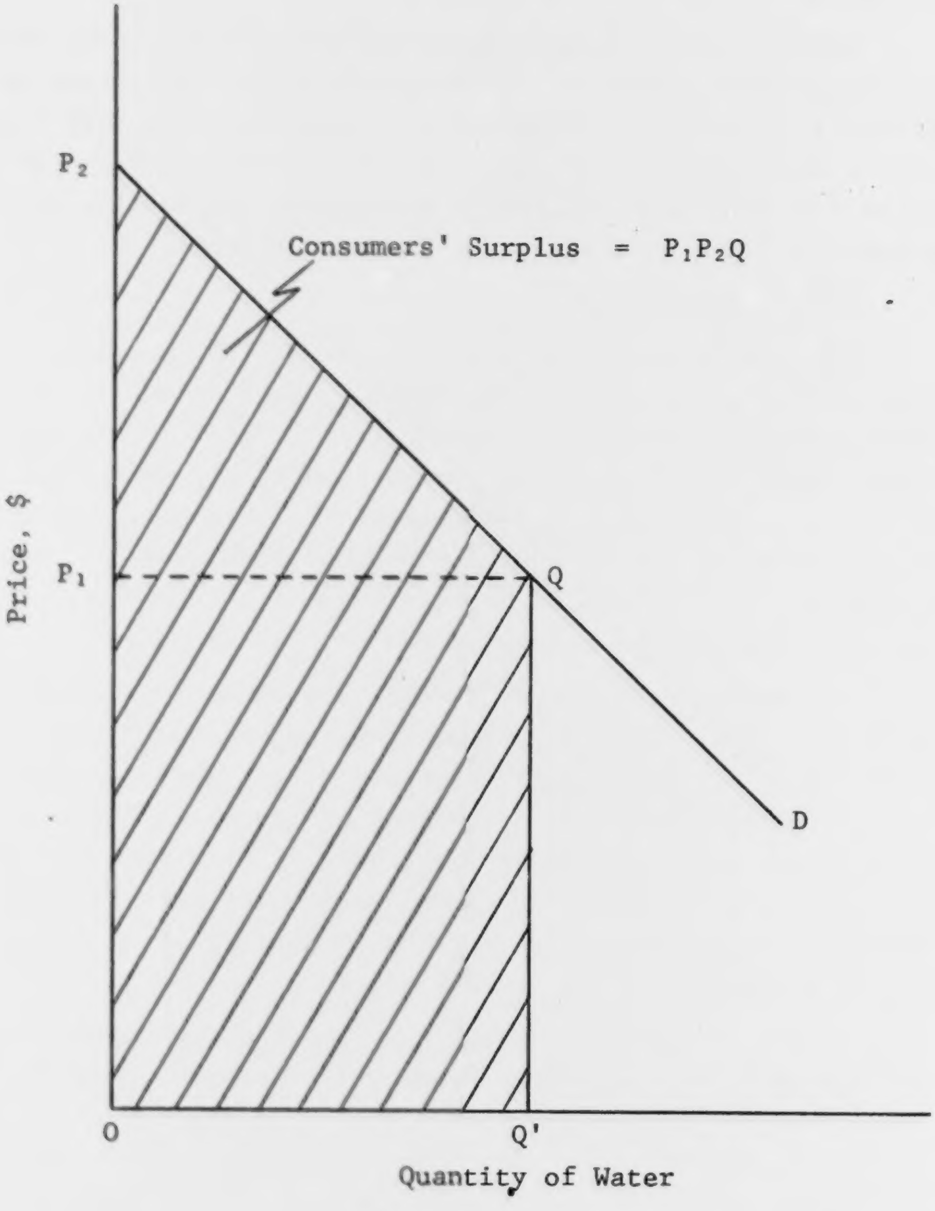


Figure 7-2

HYPOTHETICAL DEMAND CURVE

upon the constituent which is being restricted in the water, certain user groups will benefit. Table 7-1 presents a summary matrix of water quality parameters and their measured economic damage on various user segments.

Each of these 14 user areas depicted in Table 7-1 will be discussed with regard to the TDS problem for Sauget and for Illinois in general. Where it is possible to quantify benefits, such a determination is made. Any qualitative effects which exist are described to provide a complete delineation of the potential impact of TDS in the State of Illinois.

7.2.1 Aesthetics

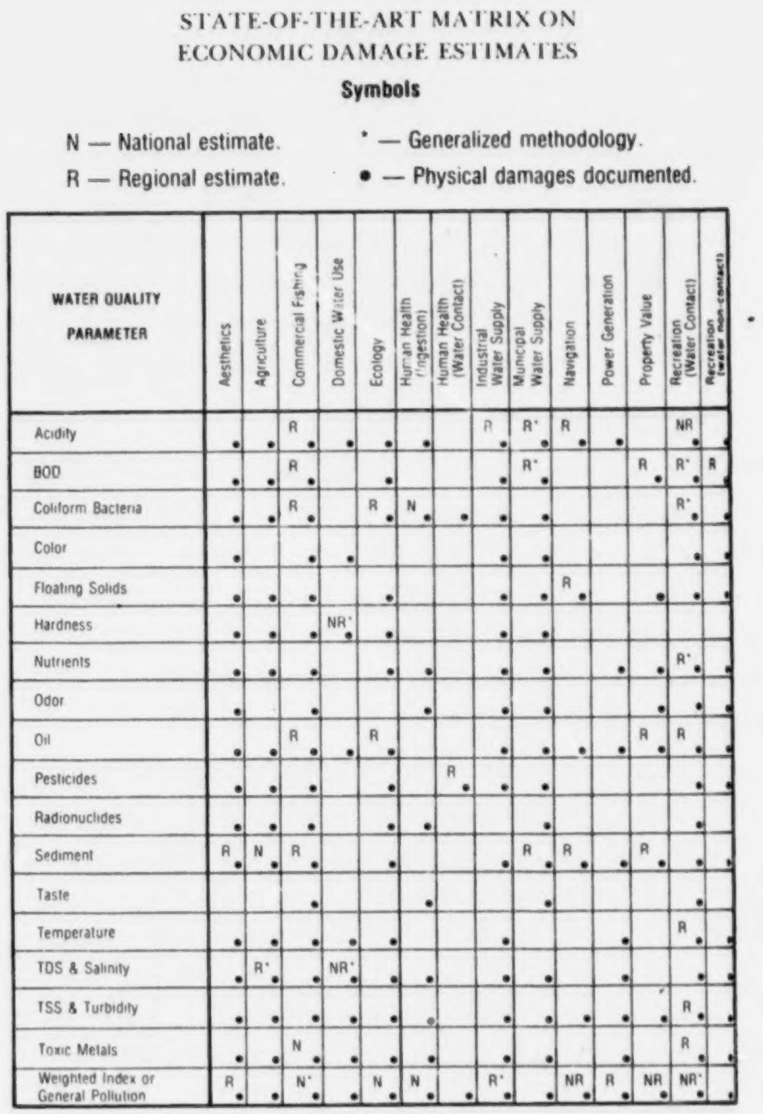
The aesthetics related to control of TDS is mainly a function of the taste in drinking water. The U.S. Public Health Service has recommended a standard of 500 mg/ℓ TDS in drinking water supplies. The actual composition of the dissolved solids in water is important in determining the threshold taste level. As was noted in the 1962 Drinking Water Standards[19], "there may be a great difference between a detectable concentration and an objectionable concentration of neutral salts".

Lockhart, Tucker, and Merritt investigated the taste threshold level of various ions on brewed coffee[19] and determined that 400 to 500 mg/ℓ chlorides or 800 mg/ℓ of sulfate as $MgSO_4$ affected the taste of coffee. In terms of TDS concentrations, such levels would be above 500 mg/ℓ and probably close to 1,000 mg/ℓ. The TDS level at which water becomes "completely unusable" is 5,000 mg/ℓ, according to the 1962 U.S. Public Health Service Drinking Water Standards.

Thebes and Chester, which are the only municipalities using the Mississippi River below Sauget, have never reported TDS levels exceeding 500 mg/ℓ. As a result of the impact of Sauget's discharge, the TDS concentration to the consumers in Chester and Thebes would not appreciably change. Thus, qualitative or

Table 7-1

STATE-OF-THE-ART MATRIX ON ECONOMIC DAMAGE ESTIMATES



STATE-OF-THE-ART MATRIX ON ECONOMIC DAMAGE ESTIMATES

Symbols

N — National estimate.
R — Regional estimate.
* — Generalized methodology.
● — Physical damages documented.

WATER QUALITY PARAMETER	Aesthetics	Agriculture	Commercial Fishing	Domestic Water Use	Ecology	Human Health (Ingestion)	Human Health (Water Contact)	Industrial Water Supply	Municipal Water Supply	Navigation	Power Generation	Property Value	Recreation (Water Contact)	Recreation (water non-contact)
Acidity	●	●	R ●	●	●	●		R ●	R* ●	R ●	●		NR ●	●
BOD	●	●	R ●		●			●	R* ●			R ●	R* ●	R ●
Coliform Bacteria	●	●	R ●		R ●	N ●	●	●	●				R* ●	●
Color	●		●	●				●	●				●	●
Floating Solids	●	●	●		●			●	●	R ●		●	●	●
Hardness	●	●	●	NR* ●	●			●	●					
Nutrients	●	●	●		●	●		●	●		●	●	R* ●	●
Odor	●		●			●		●	●			●	●	●
Oil	●	●	R ●	●	R ●			●	●	●	●	R ●	R ●	●
Pesticides	●	●	●		●		R ●	●	●				●	●
Radionuclides	●	●	●		●	●			●				●	
Sediment	R ●	N ●	R ●		●			●	R ●	R ●	●	R ●	●	●
Taste			●			●			●				●	
Temperature	●	●	●	●	●			●			●		R ●	●
TDS & Salinity	●	R* ●	●	NR* ●	●	●		●	●		●		●	●
TSS & Turbidity	●	●	●	●	●	●		●	●	●	●	●	R ●	●
Toxic Metals	●	●	N ●	●	●	●		●	●		●		R ●	●
Weighted Index or General Pollution	R ●	●	N* ●	●	N ●	N ●	●	R* ●	●	NR ●	R ●	NR ●	NR* ●	●

Source: Peskin and Seskin, Cost Benefit Analysis and Water Pollution Policy, p. 132.

quantitative, no aesthetics benefits would accrue as a result of the control of Sauget's discharge.

In the State of Illinois, only one major river, the Saline River, contains TDS concentrations greater than 1,000 mg/ℓ. At this level, there could be some aesthetic benefits as a result of taste in water, depending upon the ions present. Those counties associated with the Saline River are Gallatin, Hardin, Hamilton, Saline, and Williamson. Water with 1,000 mg/ℓ TDS is not unusable but may be unpleasant to certain individuals. There is no method to quantify the state-wide aesthetic benefits from TDS control, but these benefits would accrue primarily to surface water users in the five counties named.

7.2.2 Agriculture Benefits

In 1968, there were 61,000 farm acres in Illinois that were irrigated[20]. The total number of irrigated acres in Illinois is expected to increase to 245,000 acres by the year 2020, or to 26% of the total irrigable soils in Illinois[20]. The dissolved solids content of the irrigated water is of prime concern because of potential reductions in crop yields attributed to high mineral waters.

The effect of salinity on crop production has been investigated by many researchers. The following are suggested guidelines for salinity in irrigation waters presented in a Department of Interior study[21]:

	TDS, mg/ℓ
Water for which no detrimental effects will usually be noticed . . .	< 500
Water which can have detrimental effects on sensitive crops.	500-1,000
Water that may have adverse effects on many crops	1,000-2,000

The three major crops in Illinois -- corn, soybeans, and wheat -- are not considered salinity-sensitive crops. The following relationship between salinity and yield have been developed for these crops[22]:

	TDS Concentration Where Yield Reduction is Initiated, mg/ℓ	Rate of Yield Reduction Above Threshold, % Yield Reduction/100 mg/ℓ TDS
Corn	1,000	2.5
Wheat	3,000	1.2
Soybean	2,500	4.0

The reductions in crop yields are related to the average TDS concentration in the water supplied. Irrigation, in Illinois, usually supplies only a small portion of the total crop moisture requirement, most being furnished by normal rainfall[20]. Thus, TDS levels in Illinois waterways would have to be above 1,000 mg/ℓ before any measurable agricultural benefits could be discerned.

Of the seven major Illinois waterways described in Chapter 5, only the Saline River has a mean TDS concentration above 500 mg/ℓ. The Saline River, as shown previously in Table 5-1, has a mean TDS concentration of 1,026 mg/ℓ. Thus, _if_ sensitive crops are grown in this river basin, and _if_ irrigation constitutes a major source of water for the crops, some reduction in crop yields may occur. The number of acres in the Saline River Basin under irrigation provides a crude measure of the farmer's dependence upon irrigation. The following is a list of counties in the Saline River Basin, and their respective acres under irrigation[20]:

County	Acres Irrigated, 1968
Gallatin	80
Hardin	0
Hamilton	0
Saline	3
Williamson	0

There appears to be very little demand for irrigation in the Saline River Basin, presumably because the natural rainfall provides sufficient moisture for the crops. (If irrigation is needed in the area, one would expect a large number of acres being irrigated and perhaps the more insensitive crops being grown.)

Thus, because Illinois receives sufficient rainfall to provide a major portion of the crop moisture requirements, irrigation is not practiced as extensively as in the western states. The current TDS concentrations in the Illinois waterways are well below any harmful level for agricultural use. Rigorous enforcement of the existing TDS effluent standard or the complete elimination of the TDS regulation would have no measurable effect on agricultural use. A similar conclusion was also reached by the Natural Resources Development Board in 1970[20]. In their report to the Governor, they stated:

> "Concentration of minerals in irrigation groundwater has therefore not been reported as a problem nor is it expected to be one in the foreseeable future. Recycling of Illinois surface waters has likewise not caused build-up of mineral content adverse to irrigation."

7.2.3 Commercial Fishing

If TDS stream concentrations were detrimental to commercial fish growth, reproduction, or lifespan, then reduction or control of TDS would create a monetary benefit in pounds of fish increased. There are no major commercial fisheries in Illinois, excluding Lake Michigan and only small operations exist on the Ohio River. TDS levels in these rivers are below 500 mg/ℓ, and no quantitative benefits can be measured for improvements in these small operations.

7.2.4 Residential Water Supplies

The presence of dissolved minerals in residential water supplies inflicts some damage on appliances and personal items in contact with the water. Even at low concentrations of TDS, corrosion and accelerated depreciation of household appliances occur. The useful service life of household plumbing fixtures and appliance appears to be directly related to the TDS concentration in the water. Hardness, which may or may not be related to the TDS concentration, depending on the water source, results in scale deposits in water heaters and increased consumption in soap and detergents. Because hardness is indirectly controlled by TDS effluent regulations, hardness was considered in the benefit analysis for TDS.

Tihansky[23] provided a summary of the literature regarding the damage costs of TDS and hardness in residential water supplies. Tihansky then proceeded to develop his own, much more comprehensive estimate of the related damages of TDS and hardness. Table 7-2 lists the items for which Tihansky was able to develop mathematical relationships between damage and TDS.

Utilizing the damage estimates for the items in Table 7-2, Tihansky then developed the existing damage costs for each state; the results for Illinois are presented in Table 7-3.

Using the results of Table 7-3 and the results from Chapter 5, the potential benefits to residential water supplies from TDS regulations can be computed. First, the regulation as it pertains to the Village of Sauget will be discussed. The net increase in dissolved solids in the Mississippi River from Sauget, without any regulation, is less than 1 mg/ℓ TDS. For calculation purposes , an average increase of 1 mg/ℓ was assumed. In Illinois, downstream of Sauget there are only two public water supplies on the Mississippi, Thebes and Chester. The average per capita damage in Illinois from TDS in treated surface waters is \$12.59 per year. The average TDS level in Illinois water is 303 mg/ℓ. Dividing the per capita cost by the average TDS concentration in that state yields a damage cost of:

$$\frac{\$0.04/\text{yr}/\text{capita}}{\text{mg}/\ell \text{ TDS}}$$

Table 7-2

HOUSEHOLD ITEMS DAMAGED BY TDS AND HARDNESS

Item	Affected by
Bottle water	TDS
Cooking utensils	TDS
Faucets	TDS
Garbage grinders	TDS
Sewage facilities	TDS
Soap and detergents	Hardness
Toilet facilities	TDS
Washable fabrics	TDS
Washing appliances	TDS
Wastewater piping	TDS
Water heaters	TDS
Water piping	TDS
Water softeners	Hardness
Water utility systems:	
distribution	TDS
production	TDS
service lines	TDS
stprage	TDS
water meter	TDS

Table 7-3

EXISTING DAMAGE COSTS TO RESIDENTIAL WATER SUPPLIES IN ILLINOIS

Item	1970 Dollars	1975 Dollars[1]
Annual Damage by Source		
Treated Surface	51.6×10^6	$71.2\text{x}10^6$
Treated Ground	61.9×10^6	$85.4\text{x}10^6$
Well	56.7×10^6	$78.2\text{x}10^6$
Total	170.2×10^6	$234.8\text{x}10^6$
Per Capita Damages by Source		
Treated Surface	9.12	12.59
Treated Ground	19.14	26.41
Well	25.49	35.18
Total	15.31	21.13

[1] Cost updated by 1970 Dollars x $\frac{\text{Consumer Price Index 1975}}{\text{Consumer Price Index 1970}}$

1970 CPI = 117
1975 CPI = 162

Thus, a 1 mg/ℓ increase would result in four cents damage per capita each year. The combined population of Chester and Thebes is approximately 5,500 people, which yields an annual damage cost inflicted upon these two towns from the Sauget TDS of \$220/year. Thus, through rigorous enforcement of the TDS effluent regulation on Sauget, the benefits to downstream residential users in Illinois would be \$220/year.

Considering the regulation as it applies to the entire state of Illinois, Table 7-3 shows an annual TDS damage cost in Illinois of \$71,200,000 for treated surface waters. In Chapter 5, enforcement of the TDS regulation in Illinois was shown to reduce the TDS loadings in Illinois rivers an average of 3.1%, assuming all dischargers above 1,000 mg/ℓ are out of compliance with the add 750 mg/ℓ TDS standard. Using this maximum number, 3.1%, the annual residential damage cost could be reduced:

$$\$71{,}200{,}000/\text{year} \times 0.031 = \$2{,}200{,}000/\text{year}$$

A potential savings to the residential users of \$2,200,000 each year could be realized if the point source dischargers were all brought into compliance.

7.2.5 Ecology

The effect of TDS on the vegetation, wildlife, and general environment is a direct function of the concentration considered. According to Water Quality Criteria[21], the osmotic concentration of the body fluids of a fresh water animal is the maximum level that can be tolerated. Values above 1,500 mg/ℓ of sodium chloride adversely affect fresh water mollusks. In Table 7-4, a summary is presented of various animal and plant species, and the corresponding TDS or chloride concentrations at which some biological effect is discerned. These levels described in the Water Quality Criteria book are quite high, and no TDS effect in Illinois waters of less than 500 mg/ℓ would be anticipated based on Table 7-4.

Table 7-4

ECOLOGICAL EFFECTS OF TDS

Species	TDS or Chloride Concentration, mg/ℓ	Effect Noted
Chicken, Turkeys	3,000-5,000 (as chloride)	Death and retarded growth
Chlorella algae	6,000 (as chloride)	Growth inhibited
Waterfowl food plants	60,000 (as chloride)	Detrimental effects
Poultry	2,860 (TDS)	Threshold concentration
Swine	4,290 (TDS)	Threshold concentration
Horses	6,435 (TDS)	Threshold concentration
Dairy cattle	7,150 (TDS)	Threshold concentration
Sheep (adult)	12,000 (TDS)	Threshold concentration

Source: Water Quality Criteria, 1968.

Testimony presented by the Illinois EPA at the TDS Regulatory Hearing[24] summarized the fish-related literature; a portion is summarized below:

> "In water of 1,300 micromhos (845 mg/ℓ TDS), eggs of fathead minnow, northern pike, and walleye hatched well, but when salinity reached 4,000 micromhos (2,600 mg/ℓ) there was no hatching of walleyes, a very poor hatch of northern pike eggs, but a good hatch of fathead minnow eggs."

The following table on bluegills and diatoms was taken from the testimony presented by the Illinois EPA[24].

Compound	96-hr TL_m for Bluegill, mg/ℓ	120-hr TL_m for Diatom Nitzschia Linearis, mg/ℓ
$CaCl_2$	10,650	3,130
$CaSO_4$	2,980	3,200
NaCl	12,946	2,430
Na_2SO_4	13,500	1,900
Na_2CO_3	320	242
$NaHCO_3$	8,600	650
KCl	2,010	1,337

The information presented during the Regulatory Hearings on TDS indicated that TDS levels below 1,000 mg/ℓ could affect some sensitive aquatic species. A one-day field study on the chemical and biological condition of the Mississippi River upstream and downstream of Sauget found no significant difference in water quality or aquatic biota[25]. Since no adverse effects were found, no ecological benefits can be assigned to regulating the TDS levels in Sauget's effluent.

Within Illinois, the general stream quality is below 1,000 mg/ℓ of TDS for most streams. The Saline River contains the highest TDS concentrations, as discussed in Chapter 5. While there may be ecological damage in some Illinois waters due to the existing TDS levels, the literature indicates the damage would be small at the existing TDS concentrations. Because of the many other parameters besides TDS which influence the ecological balance in the streams, a major undertaking would be required to assess any damage associated with TDS. Thus, no general estimation of ecological benefits from TDS control can be performed.

7.2.6 Human Health (Ingestion and Water Contact)

The U.S. Public Health Service has recommended a 500 mg/ℓ level of TDS, primarily based on taste effects. More than 100 water supplies across the United States have TDS levels in excess of 2,000 mg/ℓ. Acclimatization to these levels is needed, but no ill effects have been reported[19].

The other additional effect, which is attributed to magnesium and sodium sulfate, is a laxative effect. Waters with 600 to 1,000 mg/ℓ sulfates are recognized to produce laxative effects, especially on unacclimatized persons.

The Mississippi River has not exceeded a TDS level of 500 mg/ℓ, and there are no health effects anticipated for the people of Chester and Thebes (the only downstream users of the Mississippi River) since less than 1 mg/ℓ change in TDS is anticipated from nonenforcement of the effluent regulation.

The health effects associated with other surface water users in the state from an active enforcement program of the TDS regulation are also expected to be insignificant. At the TDS levels in Illinois waterways, no health effects were reported in the literature.

7.2.7 Municipal Water Supply

The additional costs to a municipal water system of high TDS levels were incorporated in the economic damage estimate of residential water users.

7.2.8 Industrial Water Supply

Industrial users of surface waters for process and cooling purposes may experience economic damages due to high TDS levels. Damage to water pipes, boilers, plumbing, and other equipment can be incurred as the result of dissolved solids in water. In a report completed on the Los Angeles River Basin[26], the damage cost for an industrial user was estimated at $4.69/ac-ft/100 mg/ℓ TDS, or $0.014/1,000 gallons/100 mg/ℓ TDS in 1967. Upgrading the cost to 1975 dollars yields a damage factor of $0.021/1,000 gal/100 mg/ℓ TDS. Each incremental reduction in TDS can be associated with reduced costs to industrial users.

On the Mississippi River downstream from Sauget in Illinois, there are no industrial dischargers. Thus, there are no industrial benefits gained through enforcement of the TDS regulation in Sauget.

In the appendix to Chapter 5, the industrial water consumption was estimated at 1,500 million gallons per day. Approximately 250 million gallons of this amount is withdrawn from wells and the remainder is surface water. Having established the mean TDS level in the state at 303 mg/ℓ and the potential reduction in TDS with enforcement of the present standard as 3.1%, the approximate average statewide industrial savings can be estimated. Enforcing compliance of the current regulation would reduce the average TDS levels by 9 mg/ℓ. At an economic cost of $0.021 per 1,000 gallons per 100 mg/ℓ TDS, the total annual industrial savings would be $860,000, as calculated below.

$$\begin{array}{l|l|l|l} \$0.021 & 9\ \text{mg}/\ell & 1{,}250 \times 10^{6}\ \text{gal} & 365\ \text{days} \\ \hline 1{,}000\ \text{gal-}100\ \text{mg}/\ell & & \text{day} & \text{year} \end{array}$$

$$= \$860{,}000/\text{year}$$

Of course, the individual industrial savings in operation costs would vary with surface water utilized; however, as an average statewide savings, the estimate of $860,000 offers a magnitude of potential benefits.

7.2.9 Navigation

There are no known benefits to navigation in Illinois accruing from the control of TDS.

7.2.10 Power Generation

The industrial generation of power was included in the previous section discussing industrial consumers. Thus, this section deals primarily with the use of water in the utility industry. With respect to Sauget and users located downstream of the village, the Grand Tower station of Central Illinois Public Service is located on the Mississippi River. Thus, the control of TDS at Sauget would reduce operating costs for this plant.

In general, the major water use in steam generation is for condenser cooling water. The estimated damage cost of TDS on the cooling water system is based on the Water Quality Criteria[21] recommended minimum TDS quality of 1,000 mg/ℓ and the estimated plant life of 28 years. The details of the derivation of the damage cost is presented in the Appendix to Chapter 7. A damage value of $0.00018/1,000 gal/100 mg/ℓ was derived for the power-generating industry, as compared to $0.021/1,000 gal/100 mg/ℓ for industrial water. The major difference between these two values is that the power-generating industry water use is over 99% once-through cooling, while the major fraction of industrial water supply is for other uses.

For the one power plant downstream of Sauget, a decrease in the TDS level of the Mississippi River of 1 mg/ℓ would reduce the corrosion damage by $240 per year, based on the following calculations:

$$\begin{array}{l|l|l|l} \$0.00018 & 1\ \text{mg}/\ell & 360 \times 10^{6}\ \text{gal} & 365\ \text{days} \\ \hline 1{,}000\ \text{gal-}100\ \text{mg}/\ell & & \text{day} & \text{year} \end{array}$$

$$= \$240/\text{year}$$

In 1965, the entire water usage of the power industry in Illinois was approximately 13,500 MGD. To determine the effect of TDS in surface waters, those plants utilizing cooling water impoundments or lakes should be excluded. With the growth in the power generation industry since 1965, there is probably closer to 20,000 MGD utilized for cooling purposes today. However, only about half of the plants utilize the streams in Illinois, (the other half utilizing man-made cooling lakes and Lake Michigan which are unaffected by the TDS standard.) For calculation purposes, a water use rate of 10,000 MGD was utilized. As stated previously, rigorous enforcement of the TDS effluent standard would reduce the TDS levels in Illinois waterways by an average of 9 mg/ℓ. The annual savings to the electric utility industry from this reduction would be:

$$\left.\frac{\$.00018}{1{,}000\ \text{gal-}100\ \text{mg}/\ell}\right|\left.\frac{9\ \text{mg}/\ell}{}\right|\left.\frac{10{,}000 \times 10^{6}\ \text{gal}}{\text{day}}\right|\frac{365\ \text{days}}{\text{year}} = \$60{,}000/\text{year}$$

7.2.11 Property Value

The effect of TDS levels in surface waters on property values has not been quantified and is not expected to be a measurable impact.

7.2.12 Recreation (Water Contact)

Recreational activities, such as swimming or water skiing, are probably only indirectly affected by TDS levels in the water. Activities would be reduced in waters which were aesthetically unpleasing or unpalatable. No direct benefits have been ascertained for the Mississippi River below Sauget or the State of Illinois due to the existing TDS levels which are, in general, below any aesthetic threshold concentration.

7.2.13 Recreation (Water Non-Contact)

Recreational activities which are considered non-contact water sports primarily relate to fishing, boating, and camping. The effects of TDS on aquatic life were discussed in the ecology section (7.2.5). It appeared there were no measurable benefits from control of TDS on the Mississippi River. The benefits to other areas within the state in terms of aquatic effects could not be defined without extensive data collection and biological evaluations, however, these also appear to be small.

7.3 Benefits and Costs of TDS Regulation

It is important to aggregate the expected benefits for TDS control on the Mississippi River and within the State of Illinois. Thirteen categories of potential benefits have been examined, and, where possible, actual benefits quantified. The control costs for the Village of Sauget were discussed in Chapter 6, and before comparing the costs and benefits of TDS regulation, the costs within the State of Illinois must also be estimated. Thus, in the following sections, each aspect (cost and benefit) of regulation is described as it applies to Sauget's circumstances and the State of Illinois in general.

7.3.1 Expected Benefits of TDS Control

Enforcement of the existing TDS effluent regulation will result in water quality improvement. The benefits of enhanced water quality have been measured across thirteen potential user categories. In Table 7-5 the results of these estimations are summarized for Sauget and the State of Illinois.

Based on the location of Sauget and potential Mississippi water users, the economic benefits of $460/per year can be realized from enforcement of the TDS effluent standard. It should be noted that only Illinois water users downstream of Sauget were considered in this estimation. Actual external effects could be considered for users out of state and located further downstream on the Mississippi River. Since no other state bordering the Mississippi River enforces a TDS effluent standard and the primary concern is believed to be Illinois consumers, the Mississippi River analysis was restricted to Illinois boundaries.

Within the State of Illinois three user groups, residential water supplies, industrial water supplies, and utilities, were identified as receiving specific economic damage from dissolved solids in water. The residential water users represented the most significant group with a potential reduction in economic damages of $2,200,00 per year. Total benefits in the state which could be quantified equalled $3,120,000.

Table 7-5

SUMMARY OF TDS. ECONOMIC BENEFITS

Benefit Category	Benefit to Users Downstream of Sauget	Benefit to Illinois
Aesthetics	Negligible	Not measured
Agricultural Benefits	Negligible	Negligible
Commerical Fishing	Negligible	Negligible
Residential Water Supply	$220/year	$2,200,000/year
Ecology	Negligible	Not measured
Human Health	Negligible	Negligible
Municipal Water Supply	(Included in residential water supply).	
Industrial Water Supply	None	$860,000/year
Navigation	None	None
Power Generation	$240/year	$60,000/year
Property Value	None	None
Recreation	Negligible	Negligible
TOTAL	$460/year	$3,120,000/year

7.3.2 Expected Costs of TDS Control

The treatment costs for Sauget to achieve compliance with the TDS effluent standard were described in Chapter 6. Estimates of the annual costs (including the annualized capital cost) incurred ranged from $1,740,000 to $3,530,000, depending upon the method of brine disposal.

To estimate the annual compliance costs to all industrial dischargers in Illinois, a treatment scheme similar to Sauget was considered. From Table 5-2 it was noted that 8.4% of the dischargers were above the standard of 'background plus 750 mg/ℓ TDS'. Thus, if 8.4% of the industrial process water discharged required treatment, then 126 MGD would approximate the flow to be treated. As a conservative assumption the mean TDS concentration of 1300 mg/ℓ in these effluents was assumed to be reduced to 1000 mg/ℓ, or 300 mg/ℓ had to be removed. The calculations used to determine the statewide compliance costs are detailed in the Appendix to Chapter 7, and these costs ranged in value from $9,800,000 to $19,900,000 per year. This cost estimate includes annualized capital investment in addition to annual operating expenses. The range in values is attributed to variation in disposal of the brine stream which is generated.

7.4 Benefit-Cost Analysis

A comparison of the benefits and costs of TDS regulation offers an indication of the economic efficiency of the enforcement of the standard. By aggregating the potential economic damages incurred in 13 user segments due to TDS we have gained some insight as to the amount these users would be willing to pay for reduced TDS levels.

In the instance of Sauget, the potential benefits in reduced economic damages were $460 per year while the annual treatment costs alone were $1,740,000 to $3,530,000. Such a circumstance in which the costs far exceed the benefits does not meet the Pareto criterion or Kaldor-Hicks efficiency criterion. Thus, a benefit-cost analysis is not meaningful in this situation. If the marginal costs and benefits were examined, these curves would be non-intersecting and linear with slopes of zero as shown in Figure 7-3, for the TDS levels of concern. The shape and location of these curves is based on the linear relationships used to develop total cost and benefit estimates and the magnitude of these estimates. These curves would only be applicable for the existing Sauget effluent range. If sufficiently high TDS levels were reached so that other user segments were affected, then the marginal benefit (MB) curve would begin to increase, as shown by by the dotted lines in Figure 7-3.

To supply an estimate of the efficiency of the regulatory solution for controllingTDS, an alternative cost situation was considered. To reduce the TDS content of waters used by Chester, Thebes, and CIPS Grand Tower Station by 1 mg/ℓ, additional treatment of the intake water could be considered. The total municipal cost for removing this increment of dissolved solids is estimated at $8,000 per year compared to the damages incurred of $220 per year. Thus, it is more economical for Chester to remove the TDS or be paid for their damages incurred than for Sauget to control TDS. For the Grand Tower Station, however, the cost of removing 1 mg/ℓ in a 360 MGD stream far exceeds not only the economic damages but also Sauget's treatment costs. This should be an obvious conclusion because Grand Tower would remove TDS if it were more economical to do so than to suffer the present damages from TDS. In this instance the damage incurred is a much smaller cost than either treatment alternative.

A payment to the affected users equal in amount to the estimated economic damage would offer them the same welfare as would Sauget removing the TDS. Such a result would achieve the same objective as the regulation (maintain acceptable water quality for the water users) at a reduced cost. It should be noted that there are possible unquantified effects on ecology or

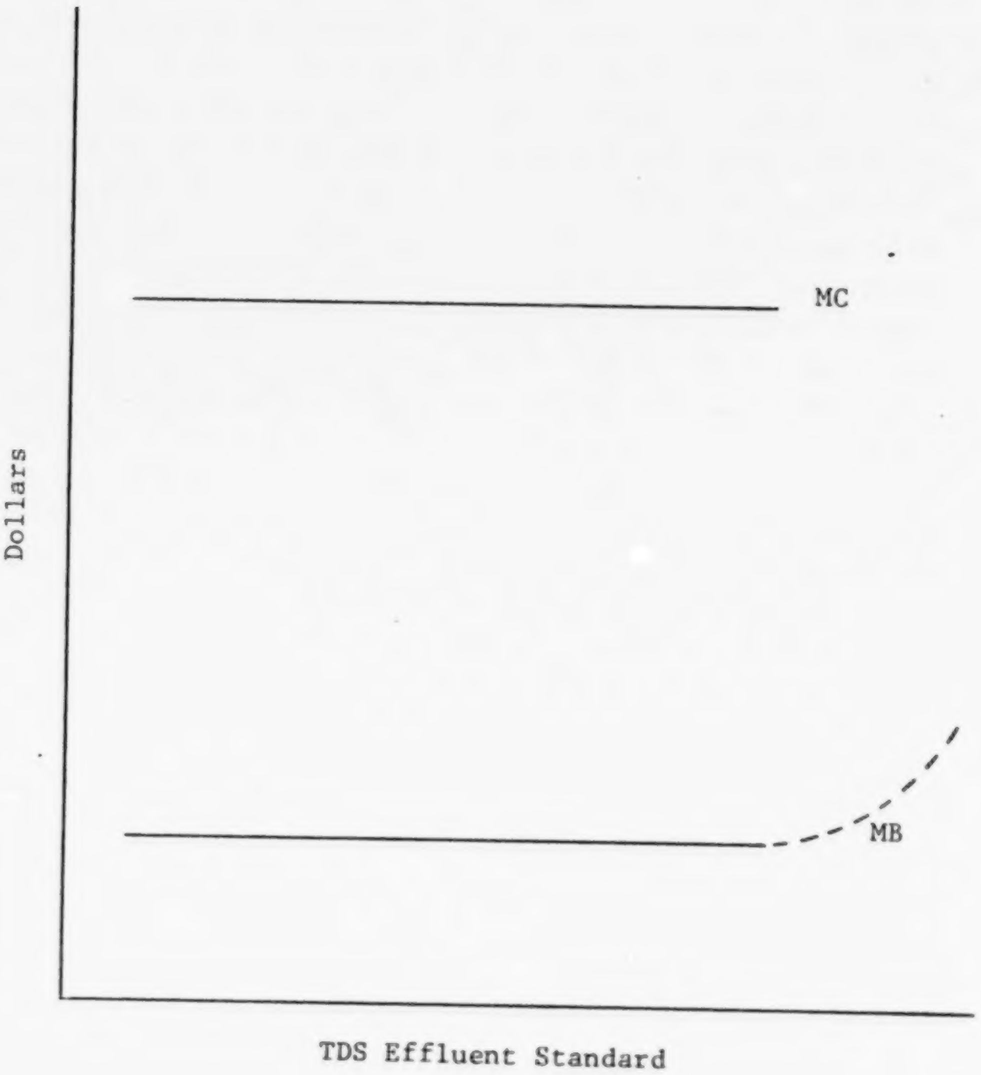


Figure 7-3

MARGINAL BENEFIT-COST ANALYSIS
FOR SAUGET

recreation, but at the level of less than 1 mg/ℓ TDS increase such effects should be insignificant.

In Illinois the total projected costs and benefits of the effluent TDS standard were also estimated. Reduced economic damage to domestic water users, industrial sources, and power plants totalled $3,120,000 per year. This value can be compared to the annual treatment cost required to bring the current TDS violators into compliance of between $9,800,000 to $19,900,00. The treatment costs are based on the use of reverse osmosis, with the range attributable to the method utilized for brine disposal. Both the statewide costs and the benefits of TDS control appear to significant on a general basis. However, the total costs do exceed the benefits to be realized, which again violates the Pareto and Kaldor-Hicks criteria. The benefits considered in the statewide analysis represent only economic damages which have been quantified. In individual circumstances within the state there may be sufficient benefit to TDS reduction to impose an effluent standard. A marginal analysis would yield curves similar to those of Figure 7-3 on a statewide average basis; however, there are exceptions to such a generalized analysis. These statewide estimates offer some perspective of the effect of the present effluent standard on the economic allocation of resources within the state.

Chapter 8

OVERVIEW OF THE ANALYSIS

Regulatory Hearing R75-6 specifically addresses exemption from the TDS effluent standard for dischargers on the Mississippi River. This regulatory change, if adopted, would affect one discharger, the Village of Sauget. There are other dischargers in Illinois, as described in Chapter 3, that also violate the existing TDS standard. While the economic impact analysis was specifically directed toward the Village of Sauget, the cost-benefit analysis was expanded to include the entire state. Inclusion of the state-wide cost-benefit analysis will provide the Pollution Control Board with additional perspective of the TDS standard.

Before examining the implications of these results with respect to TDS effluent regulations for Sauget and other areas in the state, the limits to the analysis are presented. The merits of the analysis can then be considered with full knowledge of the shortcomings and problems encountered in this study.

8.1 Limitations to the Analysis

The use of cost-benefit analyses has been limited in the past, primarily due to the lack of an adequate data base. Where reliable data have not been developed, simplifying assumptions are necessary to complete the analysis. A list of the major assumptions and methodologies utilized in this study have been completed as a limitation to the analysis. Each item is described briefly, and its potential effect on the benefit-cost analysis or economic impact is quantified where possible.

1. Number of Dischargers Violating the TDS Standard

   The effluent standard allows each discharger to add 750 mg/ℓ TDS above the background water quality; however, allowances are made for recycling and other pollution abatement practices up to a maximum of 3,500 mg/ℓ. Thus, each discharger actually has a unique TDS effluent standard (anywhere from 1,000 to

3,500 mg/ℓ TDS), depending upon the degree of recycling. The number of dischargers in violation of the 3,500 mg/ℓ standard was readily ascertained; however, the number of dischargers in violation of the law below 3,500 mg/ℓ cannot be determined without a permit-by-permit review. In Chapter 5, all dischargers with TDS levels greater than 1,000 mg/ℓ were assumed out of compliance with the standard. This assumption overestimates the actual industrial contribution that could be controlled through rigorous enforcement of the standard. However, the total treatment costs to bring industry into compliance and the total benefits of the regulation are both proportional to the number of violators. Thus, the cost-benefit analysis is not affected by the assumption that all dischargers above 1,000 mg/ℓ TDS are out of compliance.

2. Variation in Analytical Test Method

Variation in total dissolved solids analytical techniques has made it difficult to project water quality trends and actual effluent levels. The IEPA, in their routine monitoring of water quality and effluents, utilize specific conductivity to estimate TDS. The correlation between specific conductivity and actual TDS level varies for each waterway and discharger. Since the IEPA utilizes only one conversion factor for all specific conductance analyses, the accuracy of their results is suspect. In Chapter 4, the water quality trend with time was plotted for the Illinois and Mississippi Rivers. The IEPA specific conductance data had to be utilized for 1972-74, which are the key years since the adoption of the TDS standards in Illinois.

It is also interesting to note that the Illinois law specifies the 105°C evaporation test, while the IEPA stated the 180°C evaporation test was used for their non-routine analyses. There is some ambiguity as to which method is utilized for enforcement purposes by IEPA and which method should be employed for routine monitoring. This ambiguity has made it impossible to accurately identify water quality and effluent violations of the Illinois law.

3. Allocation of Treatment Costs

Allocation of costs for TDS treatment is based simply on the loading (pounds/day) contributed by each discharger to Sauget. Other considerations, such as flow and property value, were not incorporated. These other considerations are expected to have very little effect on the magnitude of the allocation. The range of values described in Chapter 6 is expected to represent typical costs incurred by each industrial discharger.

4. Price Response to Increased Costs

The price responses described in the economic analysis were based on value of shipments for typical plant sizes for the appropriate Standard Industrial Classification (SIC). Actual responses would vary across product lines and could be greater than the average values projected.

5. Uncertainty in Industrial Response

There is uncertainty in the expected response of industry to increased operating costs. Thus, the range of alternative actions is offered to depict minimum and maximum reactions.

6. Treatment Costs

A range of treatment costs was provided because of the uncertainty over the method of brine disposal. The TDS loadings utilized by the Village in their treatment cost estimate were also considerably lower than their loadings reported by the companies for the economic impact analysis. Obviously, the ultimate treatment costs are a function of the actual TDS loading and the ultimate disposal method acceptable to the IEPA.

8.2 TDS Effluent Regulation for the Village of Sauget

If the proposed TDS rule change is denied and the Village of Sauget installs a reverse osmosis treatment system, a capital investment between $7,720,000 and $12,300,000 would be required. The operating cost (excluding the annualized capital cost) would range from $840,000 to $2,830,000 per year, depending upon the disposal method.

The additional costs of operation would result in adjustments of prices, output, and employees by the industries in the Village. While the exact response of each company will not be made until a commitment for a reverse osmosis plant is requested, the range of probable responses has been provided in Chapter 6. The immediate impact on employment to a cease or desist order to the Village would be the loss of between zero and 652 jobs, with an accompanying loss of output. Future job opportunities over the next five years, which could be lost as a result of the existing TDS effluent standard, was estimated between zero to 115 jobs. Increases in some product prices could possibly be expected from enforcement of the TDS standard on the Village of Sauget, depending upon the firm's decision.

In examining the benefits gained from TDS regulations on the Mississippi River, the primary users of Chester, Thebes, and the Central Illinois Public Service Company received most of the benefits. The economic damage avoided by Sauget's compliance with the existing regulation was estimated at $460 per year. These benefits represent the savings in operation accruing to Illinois users and do not consider any external effects on users in other states.

Based simply on the existing water quality in the Mississippi River (relatively low TDS levels), effluent TDS standards do not appear to be the most efficient approach to TDS control. Alternative approaches, such as the Village of Sauget paying downstream users for their damage ($460/year) or removal of the additional TDS by the municipal water treatment plants ($8,000/year) are more cost-effective than the Village of Sauget's compliance with the existing standard (at a cost of $1,740,000 to $4,030,000/year).

There are other factors which are important in evaluating TDS regulation, such as future growth and trends in water quality. For the data available (through 1971), there is a historical trend towards increasing TDS levels in the Mississippi River at an average rate of 1.6 mg/ℓ per year. However, the average TDS concentration in the Mississippi River is still below 500 mg/ℓ. These conditions should be considered in examining Sauget's proposed amendment.

If the Illinois Pollution Control Board considers a separate TDS effluent standard for the Mississippi River, the level of compliance which could be achieved by Sauget should be studied. Using Sauget's effluent TDS concentration frequency profile shown in Chapter 3, the frequency of compliance by Sauget with various TDS effluent concentrations was computed. This estimation, shown in Table 8-1, is based upon a flow reduction from 15 MGD to 8 MGD or a doubling of TDS concentration in the effluent. Table 8-1 is only based on the existing neutralized discharge, and any future expansion which increases the TDS concentration would require treatment or be eliminated to keep Sauget in compliance. If future industrial growth is to be encouraged at the five plants in Sauget, the standard considered should be higher than the level required for compliance today.

If compliance with a daily maximum standard 100% of the time is required and the premise of avoiding TDS treatment is assumed, then Sauget would require an effluent standard of 18,000 mg/ℓ. If compliance 95% of the time were considered acceptable, then a daily maximum value of 12,000 mg/ℓ TDS would be adequate. In evaluating the proposed amendment, the Pollution Control Board should consider the significance and impact of a numerical effluent standard of 12,000 to 18,000 mg/ℓ TDS for the Mississippi River on the rest of the state. Certainly the other dischargers currently violating the TDS effluent standards would be encouraged to request similar exemptions for their waterways.

8.3 TDS Effluent Regulation for the State of Illinois

In Chapter 5, the major sources of TDS and their contributions to the waterways were identified. The industrial contribution was broken down into two segments: those discharging TDS in levels less than 1,000 mg/ℓ and those discharging greater than 1,000 mg/ℓ. The contribution from these two sources were as follows:

Industrial dischargers < 1,000 mg/ℓ TDS -- 4.3%
Industrial dischargers > 1,000 mg/ℓ TDS -- 3.1%

All dischargers with TDS levels greater than 1,000 mg/ℓ were presumed to be in violation of the existing "add 750 mg/ℓ"

TABLE 8-1

PROJECTED COMPLIANCE WITH ALTERNATIVE TDS EFFLUENT STANDARD-VILLAGE OF SAUGET

Frequency of Compliance Required of TDS Effluent Standard	Projected Required TDS Effluent Standard for Sauget, mg/ℓ
100%	18,220
95%	11,660
90%	11,000
80%	10,000
70%	9,500
60%	9,000

Source: Figure 3-1 and Table 3-1 values for 15 MGD effluent were doubled to project effluent characteristics of 8 MGD discharge.

standard. At the present time, there are no TDS removal systems (reverse osmosis, electro-dialysis, evaporation, etc.) for dissolved solids utilized by industrial dischargers in Illinois. Thus, the existing law to date has had only minimal influence on removing TDS. Rigorous enforcement of the effluent standard could reduce the state-wide TDS loading by a maximum of 3.1%, or 9 mg/ℓ. The value of an environmental regulation that excludes 97% of the pollution loading should be considered by the Pollution Control Board. Where a concentration of industries or small receiving streams results in excessive TDS levels in a stream, water quality standards offer an alternative to controlling industrial dischargers. Rigorous enforcement of the water quality standards would allow the IEPA to maintain control over the dischargers in the problem areas.

The estimated state-wide annual cost of compliance with the existing TDS regulation varied from $9,800,000 to $19,900,000. This cost was based upon the use of reverse osmosis by all dischargers with greater than 1,000 mg/ℓ TDS in their effluent. Because the interpretation of the current regulation has resulted in unique compliance levels between 1,000 and 3,500 mg/ℓ for each discharger, the actual compliance status could not be readily ascertained for each discharger.

Benefits were estimated using the same TDS reduction basis as utilized for the costs. Reduced economic damage to domestic water users, industrial sources, and power plants totalled $3,120,000 per year. These values represent state-wide estimates; however, on a case-by-case evaluation, the magnitude of the marginal analysis could certainly fluctuate. These gross numbers are only presented to indicate the approximate existing situation within the State of Illinois.

The TDS regulations within other states were examined and are summarized in the Appendix to Chapter 8. In no other state is there a numerical effluent standard for TDS; however, the increase in stream concentration over background was identified as a criterion utilized by several states for discharge regulation.

In evaluating the isolated discharger cases, it is important to be aware of the overall water quality within the state, the potential damages which may occur due to an amendment to the standard, and the actual enforcement consequences of the regulation. The Village of Sauget's effluent violations are, in part, the result of a water conservation program undertaken by the five industries in the Village. The probable economic impact upon Sauget has been described in this report although other discharger groups have been identified which may ultimately be affected by any change in TDS regulation. The overview of the state's TDS water quality and effluent situation provides the background for the decision-making process regarding the regulation of total dissolved solids.

REFERENCES

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2. Regulatory Hearing, R 75-6 before the Illinois PCB, Exhibit 5, Sept. 1975.
3. Personal communication via letter from Monsanto Corporation, April 8, 1976.
4. U.S. EPA, "Water Pollution Control in the Primary Nonferrous-Metals Industry - Vol. I - Copper, Zinc, and Lead Industries," Report No. EPA-R2-247a, Sept. 1973.
5. Personal communication via letter from Amax Zinc, April 8, 1976.
6. U.S. EPA, "Development Document for Effluent Limitations of Fabricated and Reclaimed Rubber Industry," August, 1974.
7. U.S. EPA, Economic Analysis of Proposed Effluent Guidelines: The Rubber Processing Industry, August, 1974.
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20. Ill. Dept. of Business and Economic Development, "Technical Appendix to the Report on Priority and Planning Elements for Developing Illinois Water Resources," May 1970.

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25. Regulatory Hearing R 75-6 before the Illinois PCB, Exhibit 12, Sept. 1975.

26. Koebig & Koebig, Inc., "Comprehensive Water Quality Control Plan, Los Angeles River Basin," Draft Report, 1974.

APPENDICES

Appendix to Chapter 5

SOURCES OF TOTAL DISSOLVED SOLIDS IN ILLINOIS

MASS BALANCE ON TDS LEAVING THE STATE OF ILLINOIS

There are seven major rivers that drain 94% of the total land in Illinois. Table A-1 lists these seven rivers, their drainage areas, flows, and TDS concentrations. The Illinois River alone drains 55% of the entire state, and thus carries a major portion of the state's dissolved solids load to the Mississippi.

In Table A-2, the TDS values not exceeded 10% and 90% of the times on a concentration and pounds per day basis are presented for the Illinois River. The 10% TDS concentration values occurred at flows above the mean, with four of the six flow values above the 90% frequency level. The TDS concentration values above the 90% frequency level took place at flow values close to the mean. All of the flows were above the 10% value. Based upon pounds per day of TDS instead of concentration, the results are quite different. The 10% TDS levels (in lb/day) all occurred at low flow periods with close to the mean TDS concentrations. The 90% TDS loadings all happened at high flows and five of the six values were at the 10% TDS concentration.

The above results indicate that the flow rate has considerable influence on the pounds per day of TDS entering the Mississippi River. This would suggest that storm-water runoff may be the major contributor to TDS (on a pounds per day basis) to the Illinois River, and perhaps other rivers in the state.

In Table A-3, the variation in TDS loading for each major river is presented. The median TDS level leaving the state is 44.1×10^6 lb/day, with a range from 15.2×10^6 to $139. \times 10^6$ lb/day. At the minimum level, or 15.2×10^6 lb/day, the flow and TDS contribution from storm water runoff should be negligible,

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Table A-1

MAJOR RIVERS DRAINING ILLINOIS

River	Drainage Area, mi^2	Flows, cfs				TDS, mg/ℓ			Time Period of TDS Data, and Station
		7-day, 10-yr Low Flow	10% Flow	50% Flow	90% Flow	10% Conc.	50% Conc.	90% Conc.	
Rock	10,800	1,466	1,915	4,256	15,000	295	340	425	1961-1966 at Como
Illinois	29,000	3,600	6,070	13,700	41,000	333	404*	462	1966-1971 at Meredosia
Kaskaskia	6,000	147	205	1,640	15,600	190	340	460	1961-1966 at New Athens
Big Muddy	2,400	36	36	320	5,860	200	400	940	1956-1961 at Murphysboro
Saline	1,000	3	8	140	3,950	233	1,026	1,920	1971 at Ohio River Junction
Embarras	2,300	35	54	708	5,540	250	330	390	1956-1961 at Ste. Marie
Vermillion	1,300	42	47	332	2,175	180	450	710	1958-1965 at Danville
Totals	52,800	5,329	8,335	21,096	89,125				

*Mean value, median value is 413 mg/ℓ

Table A-2

RANGE OF TOTAL DISSOLVED SOLIDS IN THE ILLINOIS RIVER

	TDS Conc., mg/ℓ	Flow, cfs
Mean	404	--
Value not exceeded:		
10%	339	6,070
50%	404	13,700
90%	462	41,000

Time Period: 1967-1971

Location: Meredosia

10% TDS Concentration Values		
TDS, mg/ℓ	Flow, cfs	Month
312	47,600	2
313	27,600	5
304	56,700	2
314	15,500	11
339	63,700	4
333	75,400	6

90% TDS Concentration Values		
TDS, mg/ℓ	Flow, cfs	Month
462	15,800	3
502	19,000	12
498	9,470	12
472	14,200	1
580	8,210	2
540	10,200	5

10% TDS Loading, lb/day			
TDS, lb/day x 10^{-6}	Flow, cfs	TDS, mg/ℓ	Month
12.4	5,900	391	10
16.5	7,560	406	9
17.6	7,530	433	11
15.0	7,740	359	9
11.9	5,200	425	9
12.6	5,750	418	10

90% TDS Loading, lb/day			
TDS, lb/day x 10^{-6}	Flow, cfs	TDS, mg/ℓ	Month
83.2	49,200	314	10
80.0	47,600	312	2
92.9	56,700	304	2
83.9	36,700	424	4
116.4	63,700	339	4
135.3	75,400	333	6

Source: R. H. Harmeson, et al., "Quality of Surface Water in Illinois, 1966-1971".

Table A-3

VARIATIONS IN TDS LOADINGS

River	Minimum TDS[1], lb/day x 10^{-6}	Median TDS[2], lb/day x 10^{-6}	90% TDS[3], lb/day x 10^{-6}
Rock	2.7	7.8	23.9
Illinois	11.9	29.8	80.0
Kaskaskia	0.3	3.0	16.0
Big Muddy	0.1	0.7	6.3
Saline	--	0.7	3.0
Embarras	0.1	1.3	7.5
Vermillion	0.1	0.8	2.1
Total	15.2	44.1	139.0

[1] 10-yr, 7-day low flow and median TDS concentration

[2] Median flow and median TDS concentration

[3] 90% flow and 10% TDS concentration

while all other major sources of TDS should remain relatively constant over a year's period. Thus, the difference between the median and minimum TDS loading is considered attributable to storm water runoff, or 28.9 x 10^6 lb/day, or 65.5% of the total TDS found in the streams that drain Illinois. Estimates of the other important sources of TDS are presented below.

CONTRIBUTIONS TO THE TDS LEVELS IN ILLINOIS

Background TDS in Lake Michigan Water

The Cook County area withdraws an average of 3,200 cfs from Lake Michigan. All of this water will eventually leave the state via the Illinois River. The mean TDS level of Lake Michigan water is 165 mg/ℓ, which yields 2.85 x 10^6 lb/day of TDS withdrawn that ends up in the waters of the Illinois River.

Domestic Waste Contribution

The national per capita increase in TDS found in domestic wastewater varies from 100-300 mg/ℓ (Metcalf and Eddy, 1972). Using a per capita consumption of 100 gal/day and an average TDS increase of 200 mg/ℓ, the loading is 0.17 lb/day/capita. While some people of Illinois use septic fields, the bulk of the population is served by sanitary sewers. Assuming the wastewater from 11 million people in the state will leave the state via the seven major rivers shown in Table A-1, the total contribution from domestic waste is 1.87 x 10^6 lb TDS/day.

Municipal Ground Water Contribution

Approximately 300 MGD of ground water is pumped out of the ground by municipalities (Water for Illinois, A Plan for Action, 1967). Utilizing a typical TDS level of 500 mg/ℓ for ground water, an estimated 1.25 x 10^6 lb/day of TDS is contributed to the rivers from municipal ground water supplies.

Industrial Ground Water Contribution

Industrial plants in Illinois utilize approximately 260 MGD (Water for Illinois, A Plan for Action, 1967) of ground water, which after use is discharged to the rivers of the state. Assuming a background TDS level of 500 mg/ℓ , this is equivalent to 1.08 x 10^6 lb/day of TDS.

Road De-Icing

According to the Salt Institute (1974), 0.3 x 10^6 ton/year of salt are applied to the highways in Illinois, or an annual average of 1.64 x 10^6 lb/day. A study in Chicago (American Public Works Assn., 1969) indicated that nearly 100% of the salt applied to highways finds its way into the waterways. Thus, the entire 1.64 x 10^6 lb/day of salt applied was assumed to contribute to the TDS in the seven river basins.

Irrigation

In many of the western states, irrigation is a major contribution to the TDS found in the rivers. Israelen and Hansen (1962) reported TDS increases from 7.4 to 77.0 mg/ℓ per river mile attributed to irrigation. In Illinois, approximately 140 square miles are irrigated. The TDS increase reported per stream mile cannot be directly applied, since the area irrigated is not reported. However, if one assumes that the salt picked up from irrigation is similar to that from storm water runoff, then the same factors can be utilized. Piemal and Nienkerk (1975) reported annual runoff values of 97-320 ton/mi^2/yr. Assuming a value of 250 ton/mi^2/yr for irrigation, the total contribution to the TDS level in Illinois is 0.19 x 10^6 lb/day.

Industrial Contribution

In 1965, the total industrial use of water, exclusive of cooling water, was 1,443 MGD (Water for Illinois, A Plan for Action, 1967). Many industries in the state have reduced their water usages over the last five years, and thus it is doubtful this water usage has increased to any great extent over the past 11 years. For our purposes, we have assumed that industrial water usage is 1,500 MGD.

The Illinois EPA samples nearly every discharger in the state each year. From the EPA's data, one can obtain a frequency distribution of TDS concentration discharged to Illinois waterways. Assuming that any discharger above 500 mg/ℓ is non-cooling water, and assuming the flow rates in each category are uniformly distributed, one can compute the total contribution of the industrial dischargers. This computation is shown in Table A-4. The total industrial contribution was estimated at 5.54 x 10^6 lb/day, of which 75% was discharged by firms within the effluent regulation, background TDS level plus 750 mg/ℓ TDS.

Table A-4

INDUSTRIAL TDS CONTRIBUTION

Industrial Category by TDS Conc.[1], mg/ℓ	Mean TDS, mg/ℓ	Mean TDS Contributed[2], mg/ℓ	% of All Industrial Dischargers	Total Contribution[3], lb/day x 10^{-6}
> 2,000	3,000	2,700	1.4	0.47
1,500-2,000	1,800	1,500	1.4	0.26
1,300-1,500	1,400	1,100	1.4	0.19
1,200-1,300	1,250	950	1.4	0.17
1,000-1,200	1,100	800	2.8	0.28
800-1,000	900	600	12.5	0.94
700- 800	750	450	16.7	0.94
600- 700	650	350	26.4	1.16
500- 600	550	250	36.0	1.13
		Total	100.0	5.54

[1] From Illinois EPA 1975 monitoring data

[2] Mean TDS minus mean background TDS in Illinois, 300 mg/ℓ

[3] Based on total industrial flow of 1,500 MGD (excluding cooling water)

References to Appendix to Chapter 5

1. American Public Works Association, "Water Pollution Aspects of Urban Runoff," FWPCA Report, January 1969.

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3. O.W. Israelsen and V.E. Hansen, Irrigation Principles and Practices, pg. 227, John Wiley and Sons, Inc., New York, 1962.

4. Metcalf & Eddy, Inc., Wastewater Engineering, pg. 232, McGraw-Hill Publishers, New York, 1972.

5. Water for Ill., a Plan for Action.

6. Salt Institute, "Survey of Salt, Calcium Chloride and Abrasive Use in the United States and Canada For 1973-74," Alexandria, Virginia.

Appendix to Chapter 6

TREATMENT ALTERNATIVES FOR SAUGET

REVERSE OSMOSIS WITH DEEP WELL DISPOSAL OF THE BRINE

A cost estimate based upon treating 5.6 MGD of the waste treatment plant's 8.11 MGD was provided by a consultant for the Village of Sauget [1]. This design, which is described in Chapter 6, includes pretreatment, reverse osmosis, and deep well disposal of the reject brine concentrate. The estimated capital investment for this plant was $7,720,000, which was based upon the following:

	Capital Investment ($)*
Pretreatment	
Filtration	850,000
Carbon Adsorption	2,500,000
Reverse Osmosis	3,670,000
Deep Well Disposal	400,000
Unaccounted for	300,000
	7,720,000

*Assumed to be 1975 dollars.

Operating cost in ¢/1000 gal treated were also developed; however, it is not clear whether the data presented includes the annualized capital investment. In the economic analysis, the labor and fuel consumption are required, thus, the following operating costs were utilized instead of the estimate provided by Sauget.

ANNUAL OPERATING COST FOR REVERSE OSMOSIS PLANT WITH DEEP WELL DISPOSAL

Annualized Capital Cost (8% cost of capital and 15 year life)	$ 900,000
Electrical Cost ($0.018/KWH) General pumps and controls -- $5,000 R.O. pumps (500 psia) -- $230,000 Deep well injection (200 psia) -- $25,000	260,000
Operating labor (1 supervisor + 1 full-time operator)	120,000
Maintenance -- Labor + Materials	230,000
Chemicals (carbon + acid)	200,000
Fuel (coal for carbon regeneration)	30,000
	$1,740,000

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REVERSE OSMOSIS WITH MULTI-EFFECT EVAPORATORS FOR REJECT BRINE STREAM

If deep well disposal is unacceptable for the disposal of the 1.4 MGD brine stream, the Village of Sauget could install a multi-effect evaporator system. A 5-stage evaporator is estimated to cost $3,000,000 [2] (1975 dollars) and require 200,000 BTU per 1000 pounds of water(2). Thus, the total capital cost for Sauget would be $10,300,000, and the annual costs are summarized below:

ANNUAL OPERATING COST FOR REVERSE OSMOSIS PLANT WITH MULTI-EFFECT EVAPORATOR

Annualized Capital Cost (8% cost of capital and 15 year life)	$1,200,000
Electrical Cost ($0.018/KWH)	
General pumps and control -- $5,000	
R.O. pumps (500 psia) -- $230,000	
Multi-effect evaporators -- $5,000	240,000
Coal (at $20/ton for evaporators)	880,000
Labor (1 supervisor + 2 fulltime operators)	210,000
Maintenance (labor + materials)	300,000
Chemicals (carbon + acid)	200,000
Sludge Disposal (50% moisture content, at $8/ton)	1,000,000
Total	$4,030,000

REVERSE OSMOSIS WITH SOLAR EVAPORATOR PONDS FOR REJECT BRINE STREAM

The Village of Sauget is located in an area that receives an average of 28" of precipitation per year, and the annual evaporation rate is approximately 58". Thus, if there is sufficient land available, solar evaporation ponds could be utilized to dry the reject brine stream. At 1.4 MGD of brine, and a pond depth of 20", 934 acres are required. If four-250 acre ponds are constructed and plastic liners installed, the estimated capital investment for the ponds and piping system to distribute the brine is $4,000,000. Assuming 1000 acres are purchased at $1000/acre, an additional $1,000,000 would be required for the land. Thus, the total capital investment for the reverse osmosis plant and evaporation ponds if $12,300,000. The operating cost is summarized below.

ANNUAL OPERATING COST FOR REVERSE OSMOSIS PLANT WITH EVAPORATION PONDS

Annualized Capital Cost -- land (8% interest)	$ 80,000
Annualized Capital Cost -- equipment (8% cost of capital and 15 year life)	1,300,000
Electrical Cost ($0.018/KWH) General pumps and controls -- $5,000 R.O. pumps (500 psia) -- $230,000 Brine distribution pumps -- $15,000	250,000
Labor (1 supervisor + 1 full-time operator)	120,000
Coal	30,000
Maintenance	300,000
Chemicals (carbon + acid)	200,000
Sludge Collection and Disposal (50% moisture at $10/ton)	1,250,000
	$3,530,000

References to Appendix to Chapter 6

1. Regulatory Hearing R75-6 before the Illinois PCB, Exhibit # 10, Sept. 1975.
2. Perry's Chemical Engineer's Handbook, Fourth Edition, pp. 11-39 to 11-41, 1963.

ESTIMATED BENEFITS TO THE POWER GENERATION INDUSTRY AND STATEWIDE TREATMENT COSTS

TDS EFFECT ON POWER GENERATION

The primary use of water in the electric utility industry is for cooling purposes. The damage cost of $0.021/1,000/gal/100 mg/ℓ TDS utilized for industrial water supply is probably a high estimate for the power generation industry, where once-through cooling water is the major source. The recommended TDS level for cooling and condensing waters is below 1,000 mg/ℓ (Water Quality Criteria, 1968), although some power plants located near the oceans utilize sea water (35,000 mg/ℓ TDS). Presumably, the criteria for cooling and condensing water is established to insure the piping, etc. will last the expected life of the plant. The estimated life of a fossil fuel plant is 28 years, (U.S. Treasury Dept. Publication No. 456 (7-62), July 1962). Assuming that TDS is the major depreciation factor on the water piping, pumping, and condensers, one can compute the damage cost. The following is an estimate of the costs for the major components affected by surface waters for a 1000 MW oil-fired plant.

Item		January 1971 Dollars
Circulating Water Pumps	(M)	$ 420,000
	(L)	50,000
De-icing water supply pumps	(M)	70,000
	(L)	15,000
Intake and Discharge Lines	(M)	293,000
(including excavation)	(L)	458,000
Warming Lines	(M)	62,000
	(L)	69,000
Discharge Tunnel	(M)	225,000
(including excavation)	(L)	452,000
Condensers	(M)	2,015,000
	(L)	500,000
TOTAL		$4,629,000

Updating to 1975 Dollars = $6,400,000

At 8% interest and 28 years, this is an annualized capital cost of = $580,000/year

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United Engineers and Constructors Inc., "Volume IV - Oil-Fired Fossil Plant - Investment Cost Study", U.S. AEC Report Wash-1230, June 1972.

A 1,000-MWE plant will use approximately 900 MGD cooling water. Converting to the same basis as was utilized for the industrial water users yields

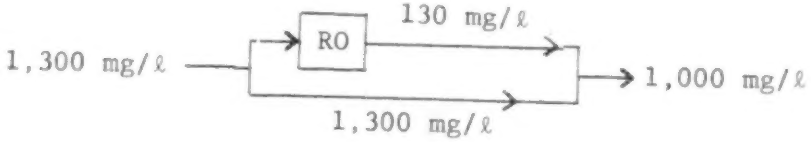
$$\frac{\$580{,}000}{\text{year}}\left|\frac{\text{year}}{365\text{ days}}\right|\frac{\text{day}}{900 \times 10^{6}\text{ gal}}\left|\frac{}{1{,}000\text{ mg}/\ell\text{ TDS}}\right.$$

$$= \$0.00018/1{,}000\text{ gal}/100\text{ mg}/\ell\text{ TDS}$$

As compared to the industrial water estimate of $0.021/1,000 gal/100 mg/ℓ, the power industry value is a factor of 100 lower. We believe, however, that the estimated value is more realistic than the industrial value. (If the industrial value is utilized, the damage cost for a water supply of 1,000 mg/ℓ TDS would be ten times the entire replacement cost each year. This is obviously a gross overestimate.)

Estimated Statewide Treatment Costs

From Table 5-2 of this report, 8.4% of all Illinois dischargers exceed the 750 mg/ℓ above background TDS standard. The mean TDS concentration of these violators is 1,300 mg/ℓ, and in order to come into compliance must reduce this level to 1,000 mg/ℓ (background + 750 mg/ℓ). If reverse osmosis units are utilized and these units are 90% efficient in removing TDS, as shown below:



then 25% of the flow must be passed through the reverse osmosis units.

From Chapter 5, industry utilizes 1,500 MGD, or 8.4% of the industries in violation utilize:

$$0.084 \times 1{,}500\text{ MGD} = 126\text{ MGD}$$

But only 25% of the 126 MGD must be treated, or 31.5 MGD. In Table 6-1, the annual cost for Sauget to remove TDS ranged from

$\$1.74 \times 10^{6}$ to $\$3.53 \times 10^{6}$, depending on the disposal site of the solids. These costs were based upon treating 5.6 MGD of wastewater containing TDS levels above 6,000 mg/ℓ. The lower anticipated TDS by most violators in the state will reduce the cost, but most dischargers are smaller than Sauget, and thus there will be diseconomies of scale. Taking a ratio of the flows, and the cost to Sauget, the cost to the other violators can be estimated:

$$\begin{pmatrix}\text{Annual Treatment}\\ \text{Costs for All}\\ \text{TDS Violators in}\\ \text{Illinois}\end{pmatrix} = \frac{31.5\ \text{MGD}}{5.6\ \text{MGD}}\ (\text{Annual Cost to Sauget})$$

The range computed is from $\$9.8 \times 10^{6}$ to $\$19.8 \times 10^{6}$ per year.

Appendix to Chapter 8

SUMMARY OF EXISTING WATER CRITERIA AND REGULATIONS FOR TOTAL DISSOLVED SOLIDS

The presence of dissolved solids in the streams and rivers of the United States is a natural occurrence. According to the National Advisory Technical Committee[21],

> "Water devoid of dissolved materials is intolerable in nature because pure water will not support aquatic life."

Recommended water quality limits for dissolved minerals are presented for the various uses of water. These values are derived from federal water criteria which has been used in establishing state water quality standards.

The general water criteria summarized in Table A-5 are based upon a literature review of aesthetic and toxic effects for each user segment. The protection of humans, animals, fish, and vegetation covers a wide range of TDS concentrations from 500 to 10,000 mg/ℓ. In waters designated as public water supplies, a TDS limit of 500 mg/ℓ is recommended for aesthetic (taste) and psychological reasons. It is interesting to note that some public water supplies have TDS levels in excess of 500 mg/ℓ. For example, the Illinois State Water Survey Bulletin No. 40 reports the following TDS levels in water supplies :

Illinois Community	TDS, mg/ℓ
Braidwood	1,199
Cuba	2,380
Glasford	1,866
Ipava	2,953
Table Grove	3,106

Irrigation of sensitive crops requires water with TDS levels between 500 to 1,000 mg/ℓ. Above this level, a reduction in crop yield will result for the most sensitive crops. All of the other water quality criteria presented in Table A-5 suggest higher TDS levels than recommended for public water supply, general farmstead use, and irrigation of sensitive crops.

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Table A-5

WATER QUALITY CRITERIA[1]

Protected Use	Total Dissolved Solids, mg/ℓ
Public Water Supply	500
Freshwater Organisms	1,500 (as NaCl)*
Wildlife	5,000 (as NaCl)
General Farmstead Use	500
Livestock	10,000
Irrigation	
Water with adverse effects on sensitive crops	500-1,000
Water with adverse effects on many crops	1,000-2,000

* 1,500 mg/ℓ increase in TDS or 1/3 over background

Source: National Technical Advisory Committee, Water Quality Criteria, FWPCA, April 1, 1968.

The water quality standards for various states are summarized in Table A-6 to indicate the variety of existing limitations. Only two types of effluent regulations have been used in other states, although there may be water quality limitations as well which would influence effluent TDS levels. In Nebraska, a discharger cannot increase the stream concentration of TDS by more than 10% or 20%, depending upon the stream. Ohio also has a restriction which limits TDS contributions from "human activities" to less than 150 mg/ℓ for certain streams. Although over twenty states have adopted water quality TDS standards, Illinois is the only state to specify TDS concentrations in the effluent of dischargers.

Water quality standards utilized in other states vary from monthly averages to specific TDS limits according to the stream classification. The range of TDS water quality standards goes from 250 mg/ℓ to 2,500 mg/ℓ. If individual stream specifications were further examined, an even wider range of limitations would occur. The monthly average water quality standard for TDS is used in six states. This method acknowledges fluctuations due to stream flow conditions, runoff, and salting activities which may temporarily exceed water quality limitations.

Table A-6

SUMMARY OF STATE REGULATIONS FOR TOTAL DISSOLVED SOLIDS

State	Total Dissolved Solids in mg/ℓ	
	Effluent	Water Quality
Alaska	--	500 - drinking water
Arkansas	--	425-450 for Mississippi R. 500 - unlisted streams
Delaware	--	250
Florida	--	500 as monthly average 1,000 as maximum value
Indiana, Kentucky, Michigan	--	500 as monthly average 750 maximum
Iowa	--	750
Louisiana, Texas, Oregon	--	Varies according to stream
Minnesota	--	500 - Class A domestic 700 - Class A wildlife 1,000 - Class B wildlife
Mississippi	--	750 - monthly average } general standard 1,500 - maximum 400-425 Mississippi R.
Nebraska	Discharger not to increase Class A stream concentrations by more than 10% and Class B by 20% or no more than 100 mg/ℓ.	600 - Class A domestic 1,500 - Class B
Nevada, New Mexico	--	500 - Class A, B, C, or 1/3 above background
New York, Tennessee, Virginia, North Dakota	--	500
Ohio	150 mg/ℓ attributed to human activity.	500 - monthly average 750 - maximum
Pennsylvania	--	500-1,500
South Dakota	--	1,000-2,500